
METAL Progress
MAY 1951

...using THERMALLOY* trays and grids for carburizing application

	Average Cost per Heat/Hour	Average Hours Life
Thermalloy	.0048¢	6707
Tray "A"	.0095¢	3443
Tray "B"	.0092¢	3022

(*Note:* Figures do not include trays damaged in furnace wrecks, by rough handling, etc.)

The trays and grids shown above are used for carburizing automotive gears at a temperature of 1650° F. Through the use of Thermalloy "50", plus certain design changes, average cost per heat/hour has been cut in half . . . average hours of service life more than doubled. (See figures at left.)

This is one of many cases where customers have greatly benefited from Thermalloy's heat-resistant properties . . . plus the ability of Electro-Alloys engineers to develop designs suited to ideal foundry practice as well as to customer service requirements.

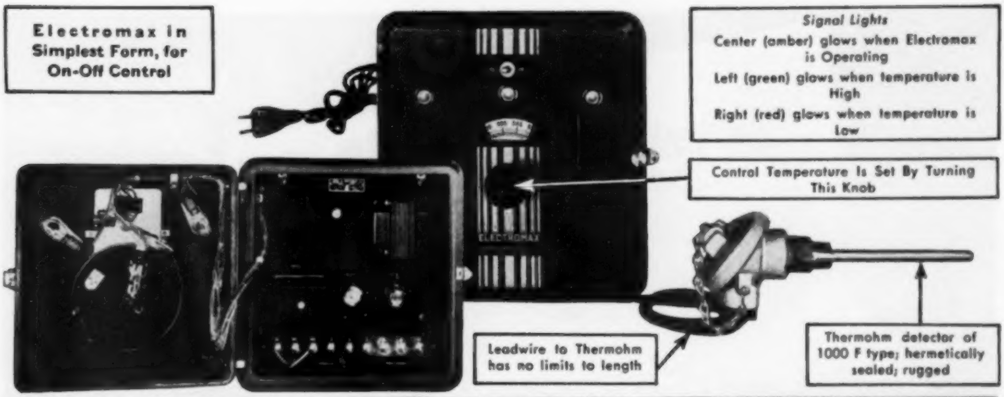
Thermalloy is not just one alloy, but a group of alloys . . . each specially adapted to certain heat and abrasion requirements. Our engineers can assist you in selecting the type best suited to your particular needs . . . recommend designs that will insure maximum service life.

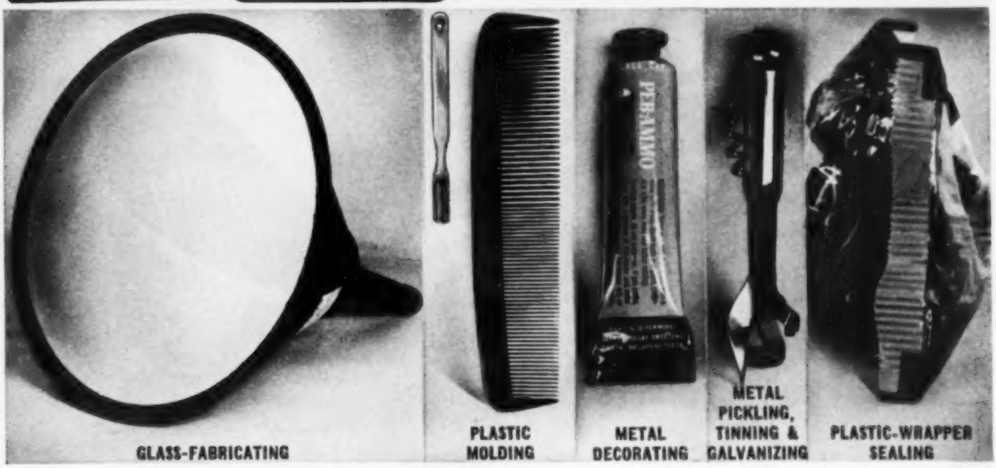
To put such knowledge to work for you, just phone your nearest Electro-Alloys office, or write Electro-Alloys Division, 2095 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO





PROTECT PRODUCTION WITH ELECTROMAX CONTROL

ELECTROMAX CONTROLLERS give modern *electronic* regulation to thousands of important manufacturing processes. They exactly fill the bill for non-recording controllers of outstanding dependability.

Electromax has the sensitivity, accuracy and dependability of its big brother Speedomax Recording Controller. Likewise, it is not affected by vibration or building tremors—can even be mounted on the frame of a molding press. The instrument needs almost no attention, because it has only one moving part—a covered, plug-in type relay. There's usually no need to open its door for months at a time.

You can specify any one of 3 types of control action:

1. On-Off or 2-position Control
2. Proportioning, automatic reset and rate (D.A.T.) Control
3. Proportioning and manual reset (P.A.T.) Control

For further information, write our nearest office, or 4927 Stenton Ave., Philadelphia 44, Pa.

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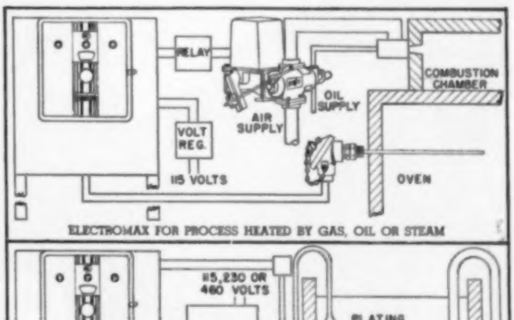

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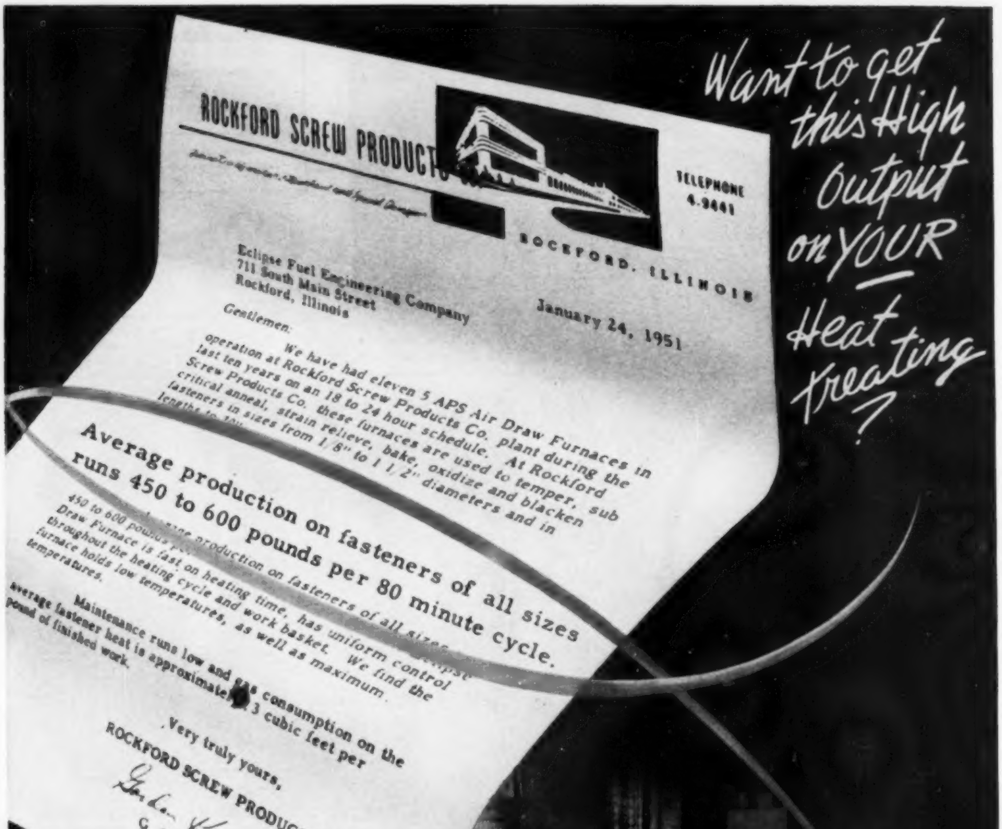
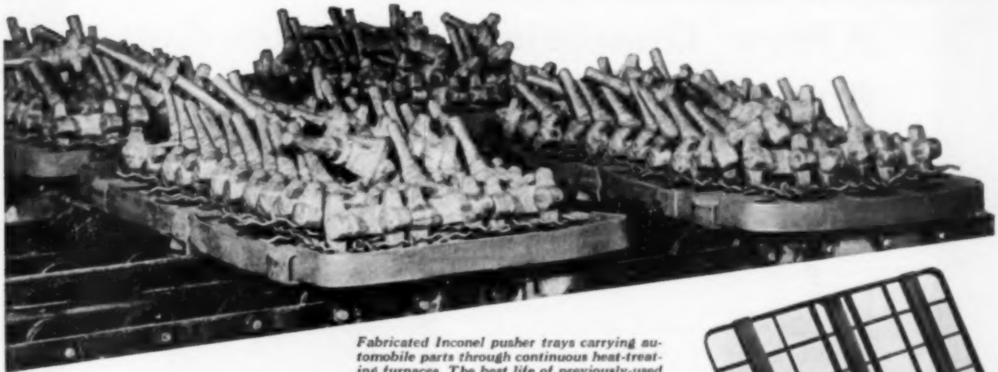


Portion of the battery of Eclipse ROTAIR AIRDRAW FURNACES in Rockford Screw Products Plant

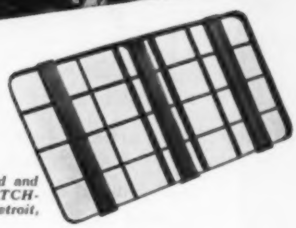
Meet a *LIGHT-WEIGHT* champion..

Inconel pusher trays still going strong on a job that licked heavier furnace trays!



Fabricated Inconel pusher trays carrying automobile parts through continuous heat-treating furnaces. The best life of previously-used trays averaged nine months. The fabricated Inconel trays have been in use over one year.

- **Furnace production increased**
- **Tray life increased**
- **Maintenance costs reduced**



Inconel pusher tray designed and fabricated by BROWN-HUTCHINSON IRON WORKS, Detroit, Michigan.

These substantial benefits are what a large automobile manufacturer gained by switching to fabricated Inconel* pusher furnace trays.

Previously-used trays weighed from 114 to 198 pounds each. The fabricated Inconel trays weigh only 86 pounds... a weight saving 28 to 112 lbs. per tray. Based on average net load of 400 pounds this represents a gross weight saving of 5 to 19% over previous equipment.

Even more important—these lighter-weight fabricated Inconel trays last longer, with correspondingly reduced replacement and maintenance costs.

This fine performance record is even more remarkable when the severity of service conditions are considered. During the heat-treating of automobile parts, the trays are subjected to temperatures as high as 1650° F., followed by oil quenching.

The furnaces, which are gas-fired and non-atmosphere in type, present high-temperature corrosion problems. Add to these punishing conditions the considerable mechanical forces acting on the trays... up to 540 pounds load plus 2000 pounds thrust from the hydraulic pusher mechanism... *and you have service conditions that demand Inconel plus good fixture design.*

Brown-Hutchinson Iron Works are designers and fabricators of these pusher trays. They, like other leading fabricators, used Inconel because of Inconel's outstanding performance record and desirable combination of physical characteristics . . . thermal durability, corrosion-resistance, high hot and cold strength, workability, economy.

Although Nickel and Nickel Alloys are currently in short supply, Inco advertisements will continue to bring you information on industrial processes and developments which we believe will be of interest.

*Reg. U. S. Pat. Off.

EMBLEM OF SERVICE INCO

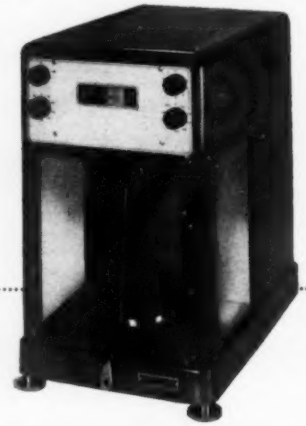
The International Nickel Company, Inc.
67 Wall Street, New York 5, N. Y.

INCONEL* ...for long life at high temperatures

FOR AMERICA'S LABORATORIES...

A New, Completely Direct-Reading Analytical Balance ...

THE *Gram-atic* BALANCE



... weighs in one-third the time required by the usual balance.

Its control knobs are manipulated to select built-in weights. Corresponding figures appear on the direct reading scale.

Weights under 100 milligrams are indicated automatically.

The Gram-atic Balance weighs samples up to 200 grams and has constant sensitivity throughout this entire range.

For 115 and 230 volt 50-60 cycle A. C. . . . . . . $895.00 each.

Fast (20 second weighing)
Eliminates all weight handling
Beam under constant load
One-scale reading
Constant sensitivity
Weighs below 100 milligrams automatically

Entire weight of sample is read on direct-reading indicator.

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Buehler specimen preparation equipment is designed especially for the metallurgist, and is built with a high degree of precision and accuracy for the fast production of the finest quality of metallurgical specimens.

1. No. 1315 Press for the rapid moulding of specimen mounts, either bakelite or transparent plastic. Heating element can be raised and cooling blocks swung into position without releasing pressure on the mold.

2. No. 1211 Wet power grinder with 3/4" hp. ball bearing motor totally enclosed. Has two 12" wheels mounted on metal plates for coarse and medium grinding.

3. No. 1000 Cut-off machine is a heavy duty cutter for stock up to 3-1/2". Powered with a 3 hp. totally enclosed motor with cut-off wheel, 12" x 3/32" x 1-1/4".

4. 1505-2AB Low Speed Polisher complete with 8" balanced bronze polishing disc. Mounted to 1/4 hp. ball bearing, two speed motor, with right angle gear reduction for 161 and 246 R.P.M. spindle speeds.

5. No. 1700 New Buehler-Waisman Electro Polisher produces scratch-free specimens in a fraction of the time usually required for polishing. Speed with dependable results is obtained with both ferrous and non-ferrous samples. Simple to operate—does not require an expert technician to produce good specimens.

6. No. 1410 Hand Grinder conveniently arranged for two stage grinding with medium and fine emery paper on twin grinding surfaces. A reserve supply of 150 ft. of abrasive paper is contained in rolls and can be quickly drawn into position for use.

7. No. 1400 Emery paper disc grinder. Four grades of abrasive paper are provided for grinding on the four sides of discs, 8" in diameter. Motor 1/3 hp. with two speeds, 575 and 1150 R.P.M.

8. No. 1015 Cut-off machine for table mounting with separate unit recirculating cooling system No. 1016. Motor 1 hp. with capacity for cutting 1" stock.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

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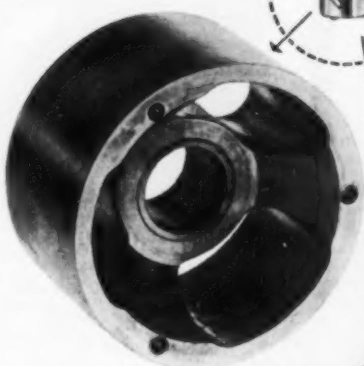
METALLURGICAL APPARATUS
165 WEST WACKER DRIVE, CHICAGO 1, ILL.

Production costs cut over 50% with HAYNES investment castings

Trade-Mark



A manufacturer of homogenizing equipment is producing stainless steel rotors and stators at half the former cost, now that he has switched from machined parts to precision investment castings. Machined parts required a total of 12 operations before they were ready for service. HAYNES investment castings require only 5 finishing operations.

The production saving on the rotor, or turbine, is 52 per cent, even though the investment-cast part costs about 6 times more than the bar stock needed for a machined part. This is because only 2 finishing operations are needed for the castings, whereas 5 operations were necessary when the parts were machined from bar stock.

The stator required 7 machining operations originally, and now requires only 3 — one of which is an electro-polishing treatment. By changing over to investment castings, the manufacturer has cut his production costs on this part 51 per cent.

For more information on the advantages of investment castings, as well as examples of successful applications, write for the booklet, "HAYNES Precision Castings."

The HAYNES investment-casting process cut the production costs of this stainless steel rotor and stator by more than 50 per cent. The parts are used in a ¼ horsepower homogenizing machine.

HAYNES
TRADE-MARK
Alloys

Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
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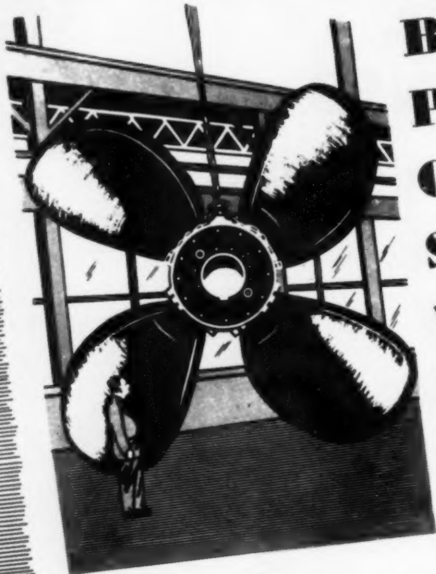
METALLURGICAL RESEARCH HAS PROVEN

Manganese Bronze Propellers Combine Strength With Resistance To Sea Water Corrosion



Shipbuilders require strong...ductile... corrosion resistant metal for propellers. Foundrymen insist upon metal having suitable running qualities...low pouring temperatures and not readily susceptible to gas porosity.

Manganese Bronze is the only metal that meets the requirements of both shipbuilder and foundryman.

Tensile strength and degree of elongation can be varied according to the need. Yes, these high tensile properties are obtained in the "as cast" condition—without heat treatment.

Specify—LAVIN NON-FERROUS INGOT—*Quality*

R. LAVIN & SONS, INC.

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REPRESENTATIVES IN PRINCIPAL CITIES

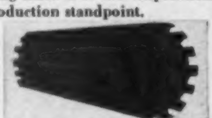
Reynolds
ALUMINUM REPORTER
A SERVICE TO INDUSTRY ON ALUMINUM USES AND DEVELOPMENTS
LOUISVILLE 1, KY. NUMBER 4

REYNOLDS FIRST PIG POURED 10 YEARS AGO

Integrally Stiffened Skin Developed for Airplanes

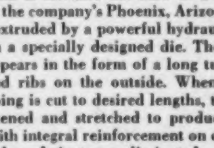
The increased pressures encountered by high speed, high altitude aircraft created new design problems. One difficulty is to get adequate skin reinforcement without increasing the dead-load to pay-load weight ratio. Even aluminum alloys that have the strength of steel do not provide the answer.

Experiments show that closely spaced T sections give the needed "beefing". However, to include them as separate structurals adds a weight penalty and labor costs for riveting mount. Milling out a thick aluminum plate to leave only a thin sheet and its reinforcing ribs is another approach. This meets weight requirements but is costly in material and machining time. It is also impractical from a mass production standpoint.



Stiffened skin as it is extruded

Presented with this problem by the Army Air Forces, Reynolds Metals Company developed a method of extruding ready-ribbed aluminum skins, without loss of metal or excessive labor requirements. A hot billet of aluminum is fed into the maw of a gigantic press at the company's Phoenix, Arizona plant and is extruded by a powerful hydraulic ram, through a specially designed die. The aluminum appears in the form of a long tube with T-shaped ribs on the outside. When cooled this tubing is cut to desired lengths, then slit, straightened and stretched to produce a flat sheet with integral reinforcement on one side. Assembly and rivets are eliminated.



Ribbed side of sheet after straightening

Present extrusion presses limit stiffened skin widths to 28 inches. Larger presses are being planned to provide the same range of sizes now common for regular rolled sheets, and possibly larger.

"Designing with Aluminum Extrusions" is a 132 page, 6" x 9" reference book that can help you make a better product at lower costs. This book is free when requested on your business letterhead. Write to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

150 Million Pounds of New Capacity Now Under Way

Just ten years ago, on May 18, 1941, the first Reynolds Aluminum pig was poured at Listerhill, Alabama. Since then the company has expanded rapidly and today has an annual capacity of over 500,000,000 pounds. This includes 50 million pounds of increased production during late 1950 and early 1951 at existing plants in Arkansas and Oregon. New construction now under way at Corpus Christi, Texas will increase Reynolds present capacity by another 150,000,000 pounds. The ever-growing organization now consists of 24 plants strategically located across the country, and employs over 18,000 people.

Pouring first aluminum at Listerhill, Ala.

R. S. Reynolds' conviction of the great need for aluminum in this country was the foundation upon which plans for production were built in 1940. In effecting these plans the whole pattern of the aluminum industry was changed. For within a single year Reynolds increased the nation's prewar aluminum production rate by 50%. This, before Pearl Harbor! And the additional output played a vital role in providing the aluminum which was so badly needed during the 1941-45 war period. The conviction which started Reynolds Aluminum production in 1941—a need for U. S. preparedness—has been constantly maintained.

R. S. Reynolds, Sr.

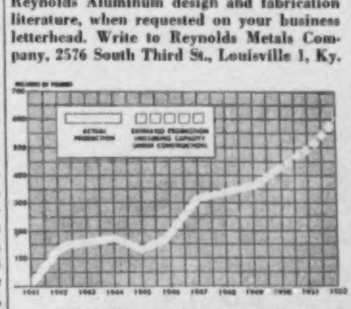
Today, the Reynolds Metals Company is constantly endeavoring to improve and expand production facilities so that a continuing and adequate supply will be available for American defense and industry. Bauxite deposits in the Caribbeans, the largest in the world, are now being developed by Reynolds to assure a nearby source of raw material for many generations. These, plus constant research to improve aluminum production methods will enable the company to keep pace with the constantly increasing demand for aluminum.

The introduction of a new primary aluminum source in 1941 has contributed greatly to the industrial growth of America. It created competition which stimulated the use of lightweight metal in the past ten years. It also provided a greater supply. Reynolds, alone, has shipped well over 3 billion pounds of aluminum to customers in this period. With an increased supply to rely on, industry has developed many new aluminum uses and applications. They can be seen today from highways to skyways, boats to buildings, in thousands of products used daily throughout the world.

Aluminum Industry Expands

Although today's mobilization requires vast amounts of material, the Aluminum Industry is adding to its facilities so that there will be a larger supply for all needs. Reynolds part in this expansion is clearly illustrated in the accompanying chart. The chart also shows the rapid production growth of the company from 1941 to 1950.

For a word and picture story on aluminum production and advantages, write for the 96 page book, "The A. B. C.'s of Aluminum." Sent free, together with a complete index of Reynolds Aluminum design and fabrication literature, when requested on your business letterhead. Write to Reynolds Metals Company, 2576 South Third St., Louisville 1, Ky.



650,000,000 pound capacity in 1952

Fans Within Fans— A New Development

Many manufacturers have improved the efficiency of their motor powered fans by adopting lightweight aluminum fan blades and hubs. When the Mathes Company of Fort Worth, Texas, consistently applied modern design ideas to aluminum, they came up with still further improvement.

The streamlined Mathes fan

Fabrication of the Mathes Fan is as far from the conventional as is its unique design. The aluminum fan blades are blanked out and formed. They are then set in precise position in a die-casting mold. The entire hub is die-cast around the blades so they become an integral part of the hub and in perfect alignment. Obviously, this cuts down assembly time and cost. Balancing is reduced to an absolute minimum.

Note internal hub design

The Mathes Company's efforts have resulted in a fan that keeps its motor cool. It is built with a conical nose section which clears the fan hub and leaves an open section between the two parts. In the nose is an interior fan which directs a stream of air over the motor, keeping it cool for efficient operation at ⅓ over the rated horsepower. When a ⅛ hp motor is used the power of a ⅙ hp unit is obtained, without overheating or undue wear on the motor. Although operating costs are practically the same as for a full ⅙ hp, the size and weight of the motor are less. Aluminum fan blades and hub also save weight.

There are opportunities continually arising where new designs and new ideas in aluminum fabrication can mean great advancements in the sale and popularity of some product you may be making.

The 12-page Product Design catalog, published by Reynolds, gives condensed information on fabrication, finishes, mill sizes and engineering tables for aluminum. Write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky for your copy today.

Aluminum foil used as Grade A wrap

Foil-on-kraft bag with vinyl heat-seal coating

Plain Aluminum Foil Re-enlists for Defense

Today, with the rapid increase in defense production, large quantities of Reynolds plain aluminum foil are going "back into uniform", much of it for the protection of packaged parts.

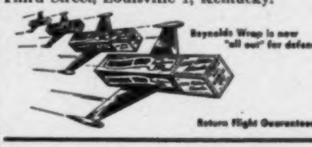
It is particularly effective as a Grade A initial wrap and was used to great advantage during World War II for the protection of surgical instruments. The present heavy demand is for both military and essential defense uses. This protective wrap seals vital parts against corrosive effects of the most severe climates around the world, from Arctic freeze to humid penetration of the Tropics. Plain aluminum foil is approved under "Spec. JAN-B-148 Barrier, aluminum foil as a Grade A grease-proof barrier."

Aluminum foil is wax-free and grease-proof on both sides. Either side can be used next to the packaged part. When properly used, it forms a positive moisture-vapor barrier which prevents any preservative greases from drying or hardening. It does not become weakened when wet, or is it affected by long exposure to dry air or extreme temperature changes.

Aluminum foil offers maximum conformity to any shaped object. This feature eliminates the necessity of taping or tying which saves time in packaging and, in some cases, considerable material.

The use of plain aluminum foil is simple. After cleaning and preserving, the part is wrapped in the proper gauge of foil. It is then packaged according to approved methods described in "Spec. JAN-P-116 Preservation, Methods of."

At the present time, grease-proof aluminum foil for parts packaging is available for defense orders. For further details and information on its application to particular products according to government specifications, call the Reynolds office listed under "Aluminum" in your classified telephone directory, or write to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.



Unique Aluminum Service Offers 30% Scrap Savings

Many manufacturers are slashing costs, solving production problems through the use of Reynolds Aluminum Fabricating Service. This service, which provides complete facilities for any desired aluminum blank or finished part, offers an average 30% scrap saving.

Reynolds pioneered the service of shipping parts instead of sheet during World War II. This made aluminum scrap available for immediate re-use, without tying up valuable transportation in the two-way hauling of unusable metal. Today, Reynolds is again supplying blanks and parts in this more efficient and economical way to expedite defense orders. Reynolds plants have round-the-clock guard systems required for such restricted military production.

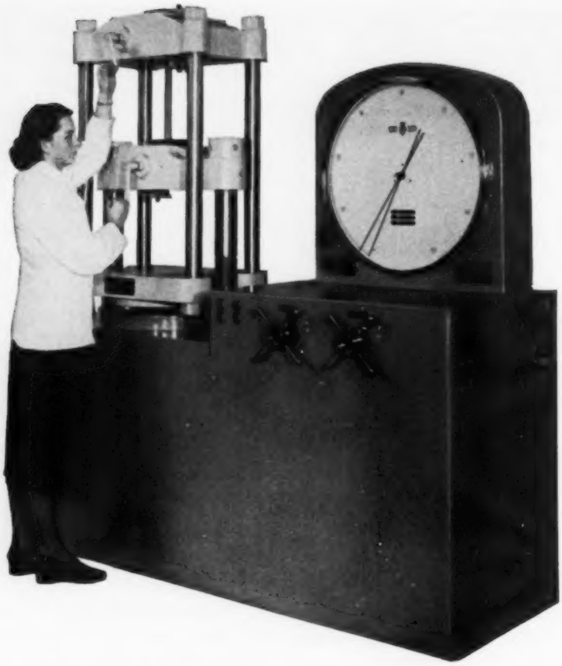
One of Reynolds fabricating plants

Included in Reynolds fabricating facilities are over 100 presses — mechanicals ranging from 5 to 1700 tons and hydraulics from 50 to 5000 tons. There is also a fully complementing line of equipment for shearing, forming, spinning, tube bending, roll forming, roll shaping, riveting, welding and finishing, to assure a steady flow of parts in quantities to meet every requirement.

A committee of aluminum design and fabricating specialists reviews each production item to determine if improvements or lower costs can be effected. The same staff also works with manufacturers' engineering departments to assure maximum benefits from aluminum in the design or re-design of their products.

1700 ton mechanical press

For complete information on how to avoid hidden costs in your parts production, call the Reynolds office listed under "Aluminum" in classified telephone directories. Or write to Reynolds Metals Company, 2065 South Ninth Street, Louisville 1, Kentucky.



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200,000 LB.

SUPER "L"

(ALSO AVAILABLE IN 60,000, 120,000, 300,000 AND 400,000 LB. CAPACITIES)

a rugged testing machine with unexcelled versatility, ease of operation, and low cost.

No other testing machine has ever combined the worthwhile features that are incorporated in the new Olsen Super "L":

- 50 to 1 spread of 3 testing ranges on one 28" dial (100 to 1 with Olsen Electronic Recorder)
- The exclusive SelecΦrange indicating system with atcotran unit which makes it possible to change ranges during test—and,
- choose the range at the flip of a switch, with automatic foolproof range indication.
- Ultra-precision, easy-read 28" dial with all three ranges color indicated.
- Simplified controls.
- Accuracy in all ranges to ASTM, U.S. Army, Navy, and Federal Specs.

The new Olsen Super "L" is a workhorse that pays its way in the laboratory or on the production floor.

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Testing & Balancing Machines

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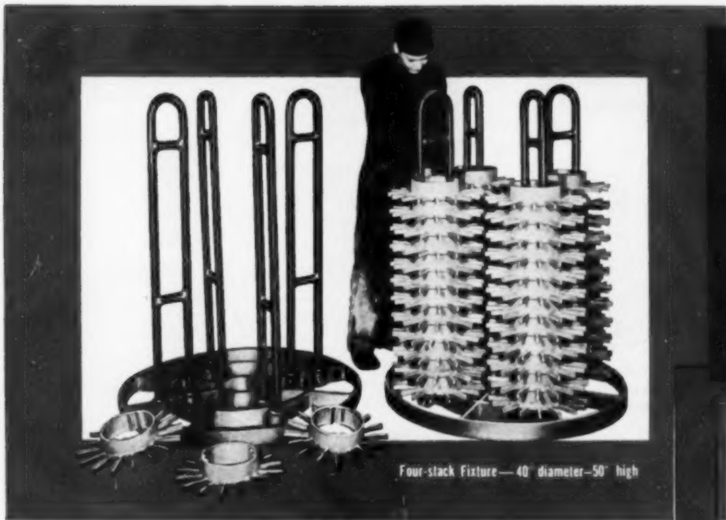

Four-stack Fixture—40" diameter—50" high

Center-post Fixture — 22" diameter—28" high

Two-level Fixture — 24" diameter—55" high

Furnace Loads Increased with D-H Fixtures "tailored for The Job"

When vertical carburizing furnaces became popular, Driver-Harris made close studies relative to loading capacities, and decided that fixtures specially designed to meet individual requirements would enable live load percentages to be increased, and loads to be more easily handled.

Custom-built equipment pioneered by Driver-Harris proved so successful that for fifteen years this firm has continued to specialize in producing furnace parts and fixtures "tailored for the job." In every instance, load ratio has been improved and load handling facilitated.

Here are a few typical examples picked from hundreds of applications in service today. These fixtures are made of Chromax* and Nichrome*—the high heat and corrosion-resistant alloys that are unsurpassed for heat-treating applications. Components consist of castings, forgings, hot rolled rod, sheet and wire—all produced in Driver-Harris' own plant to meet given requirements.

Such products exemplify the exceptional facilities at the disposal of Driver-Harris for designing and manufacturing equipment of this type. Moreover, since Driver-Harris is both producer and processor of numerous alloys, it is not prejudiced in favor of a particular material or process. Whatever is best suited to achieve peak performance is utilized. To have furnace parts and fixtures designed and produced by Driver-Harris, therefore, means that your specific needs are met in the most efficient manner possible.

Under present conditions, exceptional demand is engaging the resources of the Driver-Harris Company to an unprecedented extent. Nevertheless, we shall be happy to have you consult with us, and shall be glad to serve you to the best of our ability.

Nichrome and Chromax are manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T.M. Reg. U. S. Pat. Off.

PSC *furnishes* CARBURIZING CARRIERS *for* Every Product

Light Weight of PSC Carburizing and Annealing Equipment Cuts Heat-Hour Costs

As suppliers of the widest line of standard carburizing boxes, PSC can promptly furnish a standard type box for carburizing, for instance, ring gears of any size. But we also offer a wealth of experience in making special fixtures that will carry unusually shaped parts through carburizing and quenching to finishing, with only one handling.

PSC welded alloy carburizing boxes are used today by 80% of the nation's heat treaters. Weighing ⅔ less than cast equipment, they save handling as well as heat-up time. For instance, a study by a recent customer showed that PSC light-weight equipment cut their cycle a total of 5 hours. Lasts longer too.

Light-Weight Heat-Treating Equipment for Every Purpose

Carburizing and Annealing Boxes	Tumbling Barrels - Tanks
Baskets - Trays - Fixtures	Cyanide and Lead Pots
Muffles - Retorts - Racks	Thermocouple Protection Tubes
Annealing Covers and Tubes	Radiant Furnace Tubes and Parts
Pickling Equipment	Heat, Corrosion Resistant Tubing

PSC heat-treating units are furnished in any size, design or metal specification. Send blue prints or write as to your needs.

The PRESSED STEEL PSC

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

NEW SUPER QUENCH OIL . .

. . . GIVES YOU TRIPLE ACTION!

1 FASTER, DEEPER HARDENING

Mineral intensifiers give Park Triple A Oil faster quenching speed through the critical range, resulting in faster and deeper hardening.

2 LESS DISTORTION

Fast, uniform hardening in the critical range, plus a low cooling rate through the temperature zone of martensite formation, means less distortion from Park Triple A Oil.

Unretouched photographs of precision parts quenched from a carbo-nitriding furnace in Park Triple A Quench Oil. From left to right are parts quenched the first day, 30 days later, 60 days later, and 90 days later. Bright and clean after over 3 months use with no indication of reduction of surface cleanliness.

3 BRIGHT QUENCHING

Special anti-oxidants used in Park Triple A Oil give it greater stability for longer life and bright quenching properties. This is important when work is quenched from carbo-nitriding furnaces.

For Hot Oil Quenching up to 450° F use Park Thermo Quench Oil. Send for Bulletin No. F-7.

For These Critical Times . . .

Now more than ever you will need Park Triple A Quench Oil . . . with steels of critical hardenability due to lean alloy content and parts manufactured under government contracts, you can't afford costly rejects due to rigid inspection. Get the most from your quench oil — get Park Triple A Quench Oil today and save on critical material and expensive rejects. Send for Bulletin No. F-8 today, for complete information.

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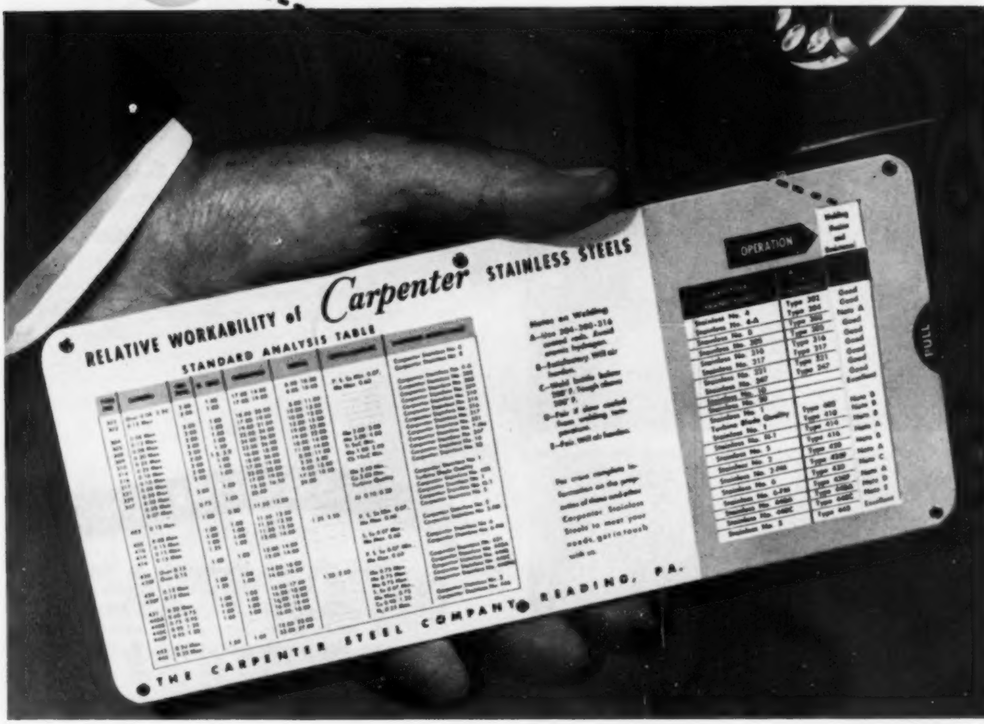
MARKS THE SPOT



Where *Carpenter* Helps You in Your Work with Stainless

Getting better machined finishes, longer tool life and fewer rejects on Stainless jobs is the answer to—

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The new Carpenter Stainless Slide Chart quickly gives you information your men need to know. It gives the relative workability for many grades, useful information for jobs where you do *blanking, deep drawing, forging, heading, machining, welding*, etc. You will also find a complete table of information on the physicals for the Stainless grades. Just drop us a note, on your company letterhead indicating your title, and we will put your Carpenter Stainless Slide Chart in the mail for you.

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Technical Notes from Du Pont

on **MOLTEN SALT BATHS**

How to avoid scumming and save cyanide

in Cyanide Case Hardening

Several rules of good operating practice should be observed if the formation of a carbonaceous scum on the bath surface is to be avoided. In addition to preventing scum formation, this procedure will permit better utilization of your cyanide supply and may provide considerable savings in your present consumption.

1. Start a new bath with Du Pont Case Hardener (30% Sodium Cyanide) or 45% Cyanide-Chloride Mixture. Never start a bath with "Cyanegg" Sodium Cyanide 96% unless used with an equal part (by weight) of refined salt (Sodium Chloride) or, preferably, in a mixture (by weight) of ⅓ "Cyanegg," ⅓ refined salt, and ⅓ soda ash.

2. Maintain the bath at 20 to 30% sodium cyanide and at proper bath level by using the replenishment salt which most closely balances the cyanide loss through decomposition and drag-out.

The following table will serve as a guide for the selection of replenishment salts under the average operating conditions of 1500—1550°F. temperature range and a decomposition rate of 0.25 to 0.30% sodium cyanide per hour.

"DRAG-OUT" LOSS (% of bath weight)		REPLENISH BATH WITH
Per hr.	Per 8-hr. day	
0.35-0.45	2.8-3.6	"Cyanegg" Sodium Cyanide
0.45-0.65	3.6-5.2	75% Cyanide-Chloride Mixture
0.65-1.0	5.2-8.0	⅔—45% Cyanide-Chloride Mixture ⅓—"Cyanegg" Sodium Cyanide
1.0-2.0	8.0-16.0	45% Cyanide-Chloride Mixture

3. Keep the bath as free as possible of carbonaceous contaminants, such as oils, carburizing compounds, etc.

4. Avoid long idling periods. If practical, accumulate work for a full day's operation and freeze the bath when not in use rather than maintaining at operating temperature for occasional treatment of work.

The above technical information is offered in the interest of increased production through efficient operation and proper use of materials. In these critical times, Du Pont Technical Service stands ready to help you with your problems. For additional information and technical help without obligation, contact the Du Pont Electrochemicals Department district office nearest you. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Dept., Wilmington, Delaware.

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... THROUGH CHEMISTRY

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for Metal Treating

NON-FERROUS MELTING

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WITH

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Want heat after heat of hard-to-handle alloy with never a complaint of contamination? At high production speeds? Without fussing around? Economically? . . . Only one furnace will do it every time—the Ajax-Northrup high frequency furnace. Melts so fast there's no time for oxidation. Nothing to contaminate. Stirs as it melts. Crucible life is long, and melting cost per pound is amazingly low. Lift coil types permit regular crucible melting. Tilting types handle larger charges, often can be poured right into the mold. Thousands are now in use—in sizes capable of handling any and all of your toughest melting jobs—cleaner and faster than you thought. Worth looking into. Ask the men who use them—or write us.

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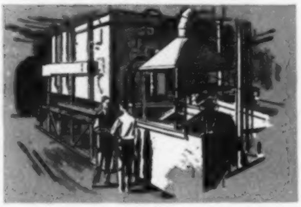

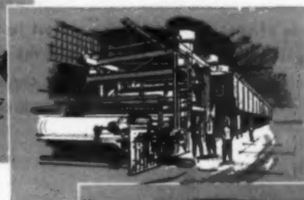


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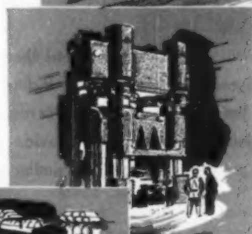
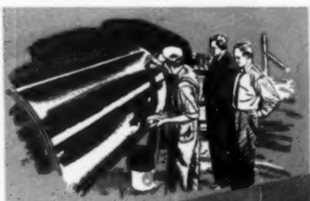

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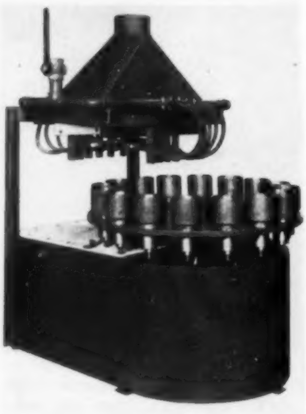
Engineering Digest of New Products

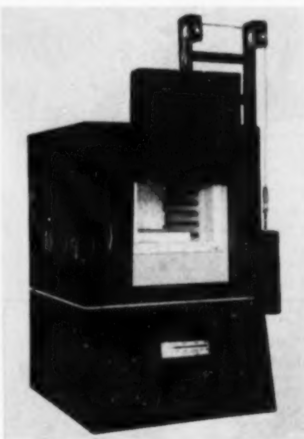
HIGH-SPEED HEATING: A new, gas-fired production heating machine has been introduced by Gas Appliance



Service, Inc. This high-speed heating unit is best suited for two types of operations: *(a)* brazing plugs or adapters into ends of shell-type units, and *(b)* annealing mouths of shell cartridges. Heat is confined to the work area and excessive heating of surrounding portions is eliminated. Cups which hold pieces are provided with spindles which rotate while passing through the heating zone. The manufacturer claims production of 600 pieces per hour in a 60-in. diameter unit. Only one operator is required for loading and unloading pieces.
For further information circle No. 363 on literature request card on p. 624B

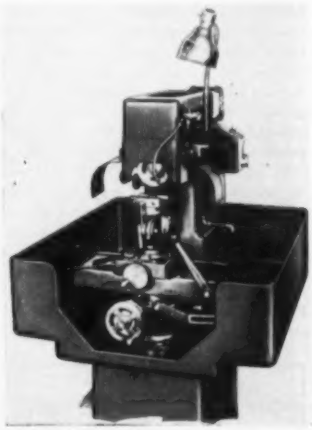
BANDSAW: Announcement of three new 15-in. bandsaw models which incorporate several new advancements in design and performance was made recently by Tyler Manufacturing Co. The new units provide speed ranges from 80 to 5000 ft. per min. by a simple turn of a handcrank. There are no belts to change and no gears to shift. From a speed indicator located at eye level, the operator can tell at a glance the blade speed of the unit so that adjustments can be made accurately. A blade tracking arrangement is incorporated, having a large yoke that places the pivot point at the crown of the upper band wheel, which holds the crown in perfect alignment with the bottom wheel at all times.
For further information circle No. 364 on literature request card on p. 624B.

HARDENING AND TEMPERING FURNACE: The new Huppert No. 869 combination hardening and tempering furnace with a Huppert Infitrol and electronic controller has been designed to give the operator automatic control of temperatures ranging from 300 to 2200° F. Heretofore on electric furnaces of this type the lower temperature could not be controlled without additional control equipment. Since it is possible to obtain temperatures below the standard range of electric furnaces, this furnace can also be used in the oven temperature range for tempering. The new furnace is 8 in. wide by 6 in. high by 9 in. deep



with maximum current consumption of 4 kw. It is wired for 220-volt single-phase operation.
For further information circle No. 366 on literature request card on p. 624B.

CARBIDE TOOL GRINDERS: A new addition to the Hammond Machinery line is a combination chip breaker and



diamond finishing grinder. The cup wheel side is for diamond finishing. The chip breaker side is not only for grinding chip-breakers but is also designed for use with the new Hammond solid carbide insert grinding fixture. Coolant is provided by self-contained pump and tank unit.
For further information circle No. 367 on literature request card on p. 624B

SAFETY VALVE: An important development in the industrial gas field, a new Lock-Tite shut-off valve is being offered by Eclipse Fuel Engineering Company to provide complete and positive safety on all gas-fired installations. Feature offered by the new valve is that it makes possible instantaneous gas shut-off under any and all unsafe conditions. It can be supplied with electric solenoid for unsafe flame conditions or with diaphragm actuators to protect against failure of either low, medium or high pressure gas and air.

One of its advantages that is designed to assure double safety protection is the manual-reset feature. In case an unsafe flame failure condition occurs, the solenoid valve

Engineering Digest of New Products

becomes de-energized, causing the gas valve to snap shut and remain shut by a coil spring. The valve then can only be opened or reset by hand, and that can be done only after the unsafe condition has been corrected. This eliminates the possibility of the valve being accidentally or deliberately blocked open.
For further information circle No. 368 on literature request card on p. 624B

ELECTRICAL SHEET: The development of an improved oriented electrical steel for use in wound transformer cores has been announced by Armco Steel Corp. Available in two grades, the new silicon steel has an exceptionally low core loss and high permeability. One grade (4W) has a core loss limit of only 0.64 watt per lb. at 15 kilogausses and 60 cycles when tested under the conditions recommended for commercial application. The corresponding limit for the other grade (3W) is 0.71 watt per lb.
For further information circle No. 369 on literature request card on p. 624B

TENSIONAL LOAD CELLS: SR-4 load cells for measuring forces or weights in tension only are announced by Baldwin-Lima-Hamilton Corp. Load capacities of the new standard Type "P" load cells are 10,000, 20,000, 50,000 and 100,000 lb. Load measurement is based on the use of special SR-4 resistance wire strain gages bonded to a load-carrying shaft. Accuracy of measurement is within $\pm\frac{1}{4}\%$ of rated capacity. The cells are temperature and modulus compensated. Successful applications include static load tests on aircraft structures and assemblies, suspension of tanks and platforms, measurement of thrust carried in tension, and cable tension testing.
For further information circle No. 370 on literature request card on p. 624B

MICROHARDNESS TESTER: Kent Cliff Laboratories have recently made major improvements in the Kentron microhardness tester used for Knoop or Vickers hardness tests. The testing load range has been increased tenfold; it now applies dead weight loads from 1 to 10,000 grams. The mechanical stage is designed so that the test specimen slides underneath high-powered objectives up to and including 1000 × magnification, without disturbing the original focusing of the microscope. A new indexed vise

for holding mounted specimens fits into the mechanical stage. By aligning vise index with an index scribed on the specimen mounting and recording the micrometer readings of the X and Y axes on the stage, impressions can be located readily any time after the original testing.
For further information circle No. 371 on literature request card on p. 624B

ABRASIVE CUTTING MACHINE: Campbell Machine Div. has announced a new wet abrasive cutting machine that cuts up to 2-in. diameter solid annealed or unannealed steel and 3½-in. diameter tubing. No adjustment of the time cycle is required, regardless of the size of stock being cut or the length of the feed up to 12 in. Every operation is automatic.
For further information circle No. 372 on literature request card on p. 624B

CATHODIC ETCHER: The availability of new, high-vacuum equipment for cathodic etching has been announced by Distillation Products Industries, a division of Eastman Kodak Co. The new equipment is based on cathodic etching principles in which the sample of metal is bombarded with glow discharge at certain low pressures. The unit is ex-

pected to be particularly useful for studying cold flow lines. Etching is produced physically rather than chemically, so that there is less danger of forming oxides and other chemical artifacts. Under the bombardment of ions the grain boundaries in metals are attacked at a different rate from the main bodies of the metal crystals, thus in many cases bringing out the crystal shapes and other characteristics of the metal with greater clarity than is possible in an acid etch.
For further information circle No. 373 on literature request card on p. 624B

PERMEAMETER: A "High-H" permeameter for magnetic testing, similar to the instrument originally built and described by Sanford and Bennett at the National Bureau of Standards, is now manufactured by the Rubicon Co. The instrument is suitable for exact measurements of normal induction, hysteresis and other characteristics of magnetic materials which require magnetizing forces up to more than 5000 oersteds. Features of the instrument are: small specimen size, direct-reading calibration system, remotely controlled flip-coil system for measuring H, double H-coil for simple extrapolation to surface of specimen, means for positioning of specimen in horizontal, vertical and lateral directions by calibrated screw adjustments, and remotely controlled reversing switch in magnetizing circuit. No special cooling system is required.
For further information circle No. 374 on literature request card on p. 624B

SPECTROMETER: A direct-reading spectrometer, the production control Quantometer, for almost instantaneous analysis of metals, is announced by Applied Research Laboratories. Based on spectroscopic principles, it embodies the additional feature of providing pen-and-ink recorded analyses of samples, element by element, within a period of 2 min. or less. A single instrument can measure 25 elements — up to 20 simultaneously.
For further information circle No. 375 on literature request card on p. 624B

D.-C. ARC WELDER: A new arc welder of the selenium-rectifier type has been announced by Miller Electric Manufacturing Co. Made in two models — 40 to 250 amp. and 60 to 375 amp. — it has arc start surge, electric current control making possible remote control operation, no moving parts, no replacement stock such as brushes or bearings, and instantaneous voltage recovery to give greater arc flexibility. The welder can be used effectively for inert gas welding; units can be paralleled for high current application.
For further information circle No. 376 on literature request card on p. 624B

MARKING TAPE: A new pressure-sensitive tape on which you can write is now available from the Labelon Tape Co. Pressure of the writing instrument rather than the lead makes the impression on the tape. The adhesive requires no moistening and will adhere to metal, wood, glass, plastics, ceramics or almost any clean surface.
For further information circle No. 377 on literature request card on p. 624B

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

378. Abrasive Wear
Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

379. Alloys, Fabricated
Catalog available showing cost-cutting fabricated heat treating equipment for higher payloads and better quality. *Rolock, Inc.*

380. Aluminum Coating
Reprints now available on Douty-Spruance article, describing protection of aluminum alloys by amorphous phospate coatings which also provide good surface for paint adhesion. *American Chemical Paint Co.*

381. Aluminum Forgings
To help you in designing for aluminum forgings, a new book is offered, covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Also a section on metallurgy gives all commercial alloy compositions, physical properties and tolerances. *Aluminum Co. of America.*

382. Aluminum Pig
12-page bulletin describes production of aluminum pig by electric reduction process in Jones Mills. *Reynolds Metals Co.*

383. Blackening Process
New bulletin illustrating and describing the Ebonol blackening process for steel, copper, brass, zinc parts. *Enthone, Inc.*

384. Blast Cleaning
Full information available on latest developments in blast cleaning and dust control equipment. *Pangborn Corp.*

385. Brazing
Ajax salt bath brazing process is fully described in bulletin 124. Shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies by this brazing method. *Ajax Electric Co.*

386. Brinell
Bench model Brinell hardness tester (Model J) is illustrated and described in bulletin. *Steel City Testing Machines, Inc.*

387. Bronzes, Cast
New catalog ready on Asarco Continuous Cast Bronzes contains physical properties, photomicrographs, table of stock shapes and sizes, weights and other valuable information. *American Smelting & Refining Co.*

388. Castings
New booklet, "Haynes Precision Castings", describes how precision investment casting process makes possible liberal use of such design features as thin-edge fillets, irregular holes, and intricate contours. *Haynes Stellite Co.*

389. Castings
Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

390. Castings, Nonferrous
16-page anniversary book, "The Lavingot", Vol. 6, No. 3, furnishes an interesting picture story of 50 years of outstanding contributions to the nonferrous metal industry. Also gives tabular information on nonferrous casting alloys and helpful notes on foundry practice. *R. Lavin & Sons, Inc.*

391. Cast Irons
"Production of Nodular Cast Irons with Cerium" gives details of actual practice in adding cerium to the foundry melt as developed by the British Cast Iron Research Association. First release in America. *Cerium Metals Corp.*

392. Cleaning Brushes
New booklet shows complete line of brushes and actual case histories of how they provide thorough cleaning of red-hot castings in 30 seconds. *Pittsburgh Plate Glass Co., Brush Div.*

393. Coatings, Metal
Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

394. Combustion Chambers, Graphite

M-9602 describes the graphite combusti chambers and "Karbate" impervious graphi burner nozzles. Outlines operation of the co plete system and points out the principal featur such as long life, absence of corrosion, minimu maintenance, ability to withstand thermal shoc simplicity and moderate installed first co *National Carbon Co.*

395. Contour Projector

New descriptive booklet available on the Kod Contour Projector, Model 2, for magnifyi dimensions, shapes and surfaces in production toolmaking. Liberal illustrations show how t projector can explore and measure deep recess in one continuous operation at high magnificatio *Eastman Kodak Co.*

396. Copper Alloys

Bulletin B-39 describes Formbrite copper-ba alloys, specially processed with superfine grain a hard surface for cold-working of brass in she strip or wire. *American Brass Co.*

397. Copper Alloy Tubes

An extensively illustrated 32-page brochu "Life Extension for Condenser Tubes", deals wi causes of corrosion and means of combating the as well as choice of materials for condenser tub *Revere Copper & Brass, Inc.*

398. Copper Welding

18-page article, "Aircomatic Welding of Copp Base Alloys", encompasses general investigati into the weldability of several copper-base allo with the recently developed inert-gas-shield metal-arc welding process. *Air Reduction Sales C*

399. Cutting Oil

New booklet available on "Gulf Periodic Cons tation Service" provides practical help on yo operating and maintenance problems. *Gulf C Corp.*

400. Die Castings

Interesting 12-page bulletin on Hoover c castings—their advantages in stepped-up produ tion, lower costs; illustrations showing how th are designed and manufactured. *The Hoo Co., Die Casting Div.*

401. Dry Cooler

Bulletin DC-50 illustrates complete line DriCoolers in a wide range of capacities and desi for specific cooling jobs. *Marley Co.*

402. Dry Cyaniding

New 4-page bulletin SC-145 presents lat developments in modern dry (gas) cyanid process, with equipment and applications. B liquid quenching and slow cooling operations described. *Surface Combustion Corp.*

403. Electron Microscope

The new table model RCA electron microsc is described and illustrated in a 12-page book *Radio Corp. of America.*

404. Finishes

Full information and samples on Iridite Al-C finishes for aluminum surfaces. *Allied Resea Products.*

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New "Black Book" gives full details on Bl Magic finishes for steel, iron, zinc, cadmium, cop and its alloys. *Mitchell-Bradford Chemical C*

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408. Furnace

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New 28-page condensed catalog 51-1 on furn and oven controls lists prices and illustra variety of instruments such as temperature c trollers, recorders and indicators, control valv etc. *Minneapolis-Honeywell, Industrial Div.*

411. Furnaces

High temperature furnaces for temperatures to 2000°F are described in leaflet. *Carl-Mayer Co*

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WHAT'S NEW

IN MANUFACTURERS' LITERAT

414. Furnaces

Illustrated literature describes newest developments in gas and electric heat treating furnaces. *Westinghouse Electric Corp.*

415. Furnaces

Complete "Buzzer" catalog available describing Buzzer high speed gas furnaces designed primarily for heat treating high carbon and alloy steels and also atmospheric pot hardening furnaces for salt, cyanide and lead hardening. *Charles A. Hones, Inc.*

416. Furnaces

Catalog 110 features new heat treating furnaces and atmosphere charts. *C. I. Hayes, Inc.*

417. Furnaces

Bulletin 346 describes new electric muffle furnaces designed to heat materials in an oxidizing atmosphere for many research, toolroom and production operations. *Harper Electric Furnace Corp.*

418. Gas Generator

Bulletin 1-11 describes how fully automatic generator Model 1 M1HE, rated 1000 c.f.h., gives accurate proportioning and assures precise analysis over full operating range. Ratio control adjusts for manufactured, natural, propane, butane or refinery gases. *C. M. Kemp Mfg. Co.*

419. Gears

Information on all types of gearing specifications including Neloy, spur, bevel, mitre, Sykes Herringbone, available in bulletin No. 9, sent on request. *National Erie Corp.*

420. Hardness Tester

Illustrated circular describing the Ames portable hardness tester in sizes for work 1 inch to 6 inches round and flat. *Ames Precision Machine Works.*

421. Hardness Testers

Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

422. Heat Treating

Barrett standard anhydrous ammonia is available in 150, 100 and 50-pound cylinders in conveniently located stock points. Send for literature. *Barrett Div., Allied Chemical & Dye Corp.*

423. Heat Treating

Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. *Ipsen Industries, Inc.*

424. Heat Treating

Pressed steel lightweight sheet alloy heat treating carriers furnished in any size, design or specification. Write for full information. *Pressed Steel Co.*

425. Heat Treating

Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam Industrial Furnace Div.*

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426. Heat Treating Equipment

Illustrated literature available on Heil impervious graphite "Nocordal" units. *Heil Process Equipment Corp.*

427. Heat Treating Small Parts

Bulletin 78 describes time-saving features of electric heat treating furnaces specially designed for small parts. *Cooley Electric Mfg. Co.*

428. Induction Heating

Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

429. Induction Melting

New bulletin 14-A tells how to master melting problems with a combination of melting speed, superfine control, and over-all economy provided by the Ajax-Northrup 20-kw converter-operated induction furnace. *Ajax Electrothermic Corp.*

430. Load Testing

Brochure 501 gives full details on universal testing machines in three ranges: Model TMU-A, 0–30,000, 0–6000, 0–600 lbs.; Model TMU-B, 0–15,000, 0–3000, 0–300 lbs. *National Forge & Ordnance Co.*

431. Melting, Induction

8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

432. Metal Cutting

New 64-page catalog No. 28 gives prices and describes complete line of rotary files, burs, metal-working saws and other products. *Martindale Electric Co.*

433. Metal-Forming Lubrication

New bulletin 426-10A describes how colloidal graphite can solve your lubrication problems in metal-forming operations at temperatures from below zero up to 5000°F. *Acheson Colloids Corp.*

434. Metallography

Catalog E-232 describes the newly designed Balphot metallograph with bright and dark field or polarized light and phase contrast ideal for grain size determinations and group viewing. *Bausch & Lomb Optical Co.*

435. Metal Spinning

New Spincraft data book No. 3—a valuable reference bulletin that illustrates lower costs made possible through pioneering developments in working of metals. *Spincraft, Inc.*

436. Metalworking Data File

Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

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	0.2	0.5	0.8	1.0	1.5	2.0	2.5	3.0	4.0
10 mc	−0.14	−0.36	−0.27	−0.11	+0.37	+0.78	+1.15	+1.40	+1.70
20 mc	−.09	.00	+.41	+.76	+1.57	+2.16	+2.63	+2.91	+3.21
50 mc	−.01	+.47	+1.31	+1.90	+3.15	+4.00	+4.57	+4.90	+5.20
100 mc	+.06	+.82	+1.99	+2.77	+4.34	+5.38	+6.06	+6.41	+6.71
200 mc	+.10	+1.17	+2.67	+3.63	+5.54	+6.77	+7.82	+7.92	+8.21
500 mc	+.17	+1.64	+3.57	+4.78	+7.12	+8.60	+9.47	+9.91	+10.21
1 c	+.23	+1.99	+4.25	+5.65	+8.31	+9.99	+10.95	+11.41	+11.71
2 c	+.28	+2.35	+4.93	+6.52	+9.51	+11.37	+12.42	+12.92	+13.22
5 c	+.36	+2.81	+5.82	+7.66	+11.09	+13.21	+14.37	+14.91	+15.21
10 c	+.41	+3.17	+6.50	+8.52	+12.28	+14.59	+15.85	+16.42	+16.72
20 c	+.47	+3.52	+7.18	+9.39	+13.48	+15.98	+17.32	+17.93	+18.23
50 c	+.54	+3.99	+8.06	+10.54	+15.06	+17.81	+19.27	+19.92	+20.22
100 c	+.60	+4.34	+8.76	+11.40	+16.25	+19.20	+20.75	+21.43	+21.72
Danger range	Plus	Plus	Plus	Plus	Plus	Plus	Plus	Plus	Plus
20 cm	+0.26	+1.64	+3.16	+4.02	+5.55	+6.44	+6.85	+7.00	+7.00
50 cm	+.11	+.71	+1.36	+1.73	+2.39	+2.77	+2.95	+3.01	+3.01
1 m	.00	.00	.00	.00	.00	.00	.00	.00	.00
2 m	−.11	−.71	−1.36	−1.73	−2.39	−2.77	−2.95	−3.01	−3.01
5 m	−.26	−1.64	−3.16	−4.02	−5.55	−6.44	−6.85	−7.00	−7.00
10 m	−.37	−2.35	−4.82	−5.76	−7.94	−9.21	−9.80	−10.01	−10.01
Working [illegible], hr/day	Plus	Plus	Plus	Plus	Plus	Plus	Plus	Plus	Plus
1	−0.17	−1.06	−2.04	−2.60	−3.50	−4.16	−4.42	−4.52	−4.52
2	−.11	−.71	−1.36	−1.73	−2.39	−2.77	−2.95	−3.01	−3.01
4	−.06	−.35	−.68	−.87	−1.20	−1.39	−1.47	−1.51	−1.51
8	.00	.00	.00	.00	.00	.00	.00	.00	.00
24	+.09	+.56	+1.08	+1.37	+1.89	+2.20	+2.34	+2.39	+2.39

THICKNESS OF LEAD REQUIRED FOR SHIELDING FROM GAMMA RAY SOURCES
(Table prepared by the NATIONAL BUREAU OF STANDARDS)

Select the column for the energy required. The entry gives thickness in centimeters of lead for different radiation strengths at 1 meter for 8 hours per day to give 50 milliroentgens. Then add algebraically the correction terms for other working ranges or times to obtain the shield thickness required.

Example: Shield is required for the manipulation of 500 millicuries of radioactive material emitting 1.8 electron volts (Mev) gamma rays at a minimum working distance of 50 cm., and for 4 hr./day.

Shield thickness $= \underset{(a)}{8.60} + \underset{(b)}{2.77} - \underset{(c)}{1.39} = 9.98$ cm. of lead in which

a = basic entry.

b = correction for danger range = 50 cm.

c = correction for 4 hr./day.

The harnessing of atomic energy has brought with it the problem of controlling the powerful rays emitted during atomic disintegration. Basically, protection from these rays is similar to the protection afforded by lead against the harmful effects of X-rays and radium emanations. Despite the enormous penetrating power of the rays emitted by atomic pile reactors, lead is still the most important metal for guarding personnel against harm by radiation exposure.

The impermeability of the shielding material is a function of its density. Lead, which is the densest commonly available metal, will give the greatest protection per unit of thickness, and for that reason is the least bulky and usually the lightest and most economical for such shielding. Other advantageous properties which recommend the use of lead for this purpose can be summarized thus: • Lead is relatively abundant, low in cost and has a high salvage value • Lead is radioactivation-proof; it does not become contaminated by exposure to radiation and thus may be used continuously without fear of itself becoming radioactive • Metallic lead has an advantage over various aggregate materials such as concrete in that a *uniform* density is guaranteed throughout • Lead is easily utilized for this purpose; in the form of brick it is readily shifted from place to place for temporary protective requirements.

Since none of its physical and chemical characteristics are altered by this type of service, the metallic lead used in radiation-barriers is recoverable and thus increases the nation's strategic, lead-in-use stockpile.

One face of the Clinton chain-reacting uranium pile is equipped with holes for experimental purposes. Two physicists are demonstrating an experiment with a defined beam of radiation emerging through hole No. 20. The thick house of lead bricks in the foreground stops the beam after passing the experimental device. Lead bricks in background are available for shielding wherever needed. U. S. Signal Corps photo

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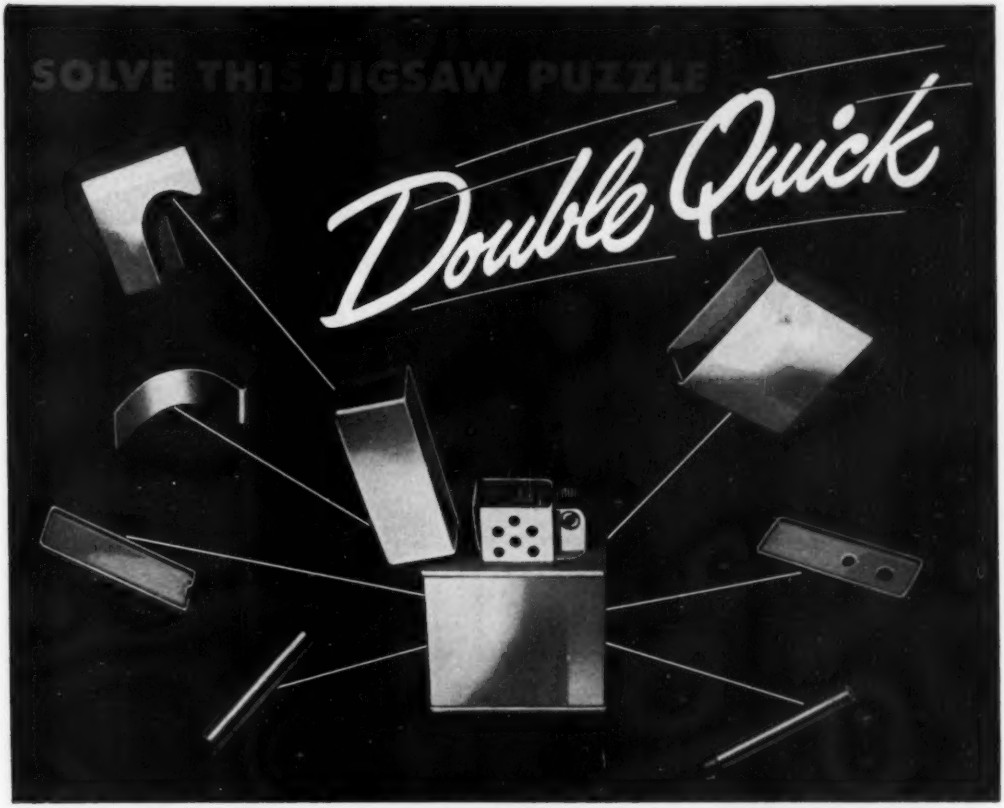

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The American Emblem Co. wanted to speed production, cut costs and reduce rejects in the assembly of their "Ruliter" Cigarette Ignitors. Look what happened when they switched from hand soldering to automatic TOCCO soldering!

COSTS DOWN—Solder cost reduced 50%—repairs and rework due to misalignment of parts cut 98%.

PRODUCTION UP—A 7½kw 9600 cycle TOCCO unit with conveyor type fixture heats one assembly every 20 seconds—twice the former output.

REJECTS ELIMINATED—Formerly rejects due to leaking seams and uneven heating were frequent. TOCCO has eliminated these completely.

TOCCO ENGINEERS—are glad to survey your soldering, brazing, hardening or forging requirements to see where TOCCO can save you time and money, too.

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Check These Important Advantages

- *Affords multi-point recording for both controlled and non-controlled temperatures.*
- *Available for a wide variety of contact and proportional control systems.*
- *Controls at the same or different temperatures.*
- *Conserves panel space.*
- *Reduces initial cost.*

In many applications, the desirability of having a number of controlled and non-controlled related records on the same chart, for convenient comparison, has long been recognized. The high speed of response plus the high speed selective action of the *ElectroniK* Potentiometer now makes it entirely practical to control several points from one instrument.

The instrument can be used to control several furnaces or several zones in one furnace . . . to provide both furnace and work temperature control or high limit control . . . to furnish a number of controlled and non-controlled records on the same chart.

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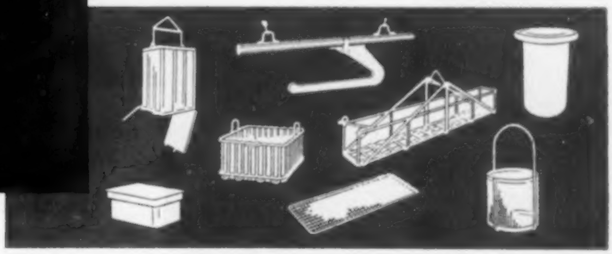
CASE HISTORY
NO. 2

Photo shows installation at the Bassick Co., Bridgeport, Conn., of a Rolock alloy Drop-Bottom Basket used with a pit-type furnace.



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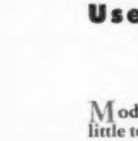

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May, 1951

Volume 59, No. 5

Metal Progress

Cover by Harry Levy

Technical Articles

Critical Points, by The Editor

Departments

Abstract of an Important Article

Here is a picture you helped us to paint

This month of May marks an important milestone in our relationship with you. It's the 50th birthday of our Indiana Harbor works.

Naturally we're a little proud of the growth of "The Harbor" from a sandy wasteland to an efficient steel-making facility. But, more than that, we're grateful to you . . . our customers, suppliers and friends . . . for making the growth possible.

So, without the usual anniversary platitudes, we say sincerely, "Thanks."

(By the way . . . the picture on the right is rapidly becoming obsolete as we further expand our ingot producing facilities by another 20%).

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By The Editor
of *Metal Progress*

Critical Points

High-Quality Castings

DURING A TRIP to California to attend the Society's Western Metal Congress and Exposition (and a right smart metals exposition it was indeed, together with a notable series of high-grade technical sessions), The Editor had the advantage of discussing steel castings with a number of intelligent metallurgists. The range of product was large — from bulldog castings for grinding ores to accurate parts of aircraft quality, from enormous water wheels ("runners") for power plants to their tiny cousins for turbo-superchargers. From these conversations some puzzling paradoxes emerged.

Take, for example, the runners of a Francis reaction turbine — substantially a series of curved vanes set between outer shroud-rings and central shaft. These vanes change the direction of the water entering the passages, and the thrust of the issuing streams turns the shaft. The action is fundamentally the same as in a steam turbine or in a gas turbine — in fact, little imagination is required to see the kinship of a water wheel 14 ft. in diameter and a turbo nozzle box of 14 in. The neophyte might guess that the 14-in. casting would be easier to make, yet deliveries to AiResearch Mfg. Co. of Los Angeles from foundries specializing in "precision investments" are sporadic and of variable quality. On the other hand, Pelton Water Wheel Co. of San Francisco is getting satisfactory 30-ton carbon steel runners for pumps at Grand Coulee dam from Columbia Steel Co. in Pittsburg, Calif. (primarily a steel plant rather than a steel foundry), and 8-ton runners for reaction turbines from General Metals Co. in Oakland cast entirely in 18-8 chromium-nickel stainless steel.

Turbine runners

Immediately objections can be raised to such a comparison between hydro-power plant and aircraft castings, based on the existence of different levels of precision, quality, stress intensity and size. All these terms are relative. Precision of Pelton's castings is high enough that the wheel's efficiency is 92%. Quality is high enough for the big runners to transmit 65,000 hp. — not in short bursts, but hour after hour, months on end. They meet the required service. Good enough is sufficient; anything better is likely to be wasteful — these truisms, one suspects, are sometimes forgotten by aircraft engineers when they write specifications for castings.

As a matter of fact, stress intensity and size are two factors that will force aircraft designers to turn to steel. Intricacy of design also indicates that fabrication of such forms — if possible — will be excessively wasteful in man-hours. For example, nose beams on new bombers are already too long for the biggest presses, built or building, for forging aluminum. Stresses are going up: For the training planes of 1940 they were on the order of 7000 psi.; in fast fighters they are now closer to 17,000. Again, shape: Wings of supersonic craft ideally are razor blades, too thin to build up of small parts, the skin heated by friction beyond the safe limit for light metals. Hogging such a shape out of a big slab seems a poor substitute for casting it close to shape in the beginning.

Shape, size, stress, operating temperature, all point to a new era in constructional methods and metals for aircraft, and something must be done to avoid a roadblock in progress, through lack of man power in a war emergency, or deficiencies in the conventional aircraft techniques.

Steel castings of integrity seem to be a logical alternative, but reasons for the aeronautical engineer's suspicion of castings are easily apparent. Only to watch the construction of a modern airframe is to see what extraordinary efforts have been made to refine and perpetuate the mechanical assembly of bits and pieces. Undoubtedly the builder feels that he can inspect each part as it is formed from sheet, bar or forging; being then sure of its quality he joins it to another first-class part and inspects the joint appropriately. Step by step these

Fabricated parts versus steel castings

searching inspections proceed, and in the end he delivers a completed machine, theoretically with no weak spot.

He can't do this with a casting. He turns to a casting only when a part is too intricate to fabricate or practically impossible to forge or machine, and so he gets a shape — and nearly always he doesn't like it. It isn't smooth enough. It isn't of exact size. He isn't sure that the test coupon is representative. He suspects invisible cracks, and his Magnaflux or Dy-check may give him some proof. He suspects interior unsoundness, cracks, porosity, or segregation, and his X-ray or ultrasonic machines can always turn up some "indications". He is doubtful whether it is good enough; he must take no chances, and so the casting goes back to the vendor who growls about the unnecessarily high and impossible requirements.

The foundryman doesn't particularly want such business; it's only a headache and he can make a living making stuff that doesn't have to fly. There is hardly enough continuity or tonnage, nor a sufficiently firm community of interest or basis of mutual respect, for a progressive foundry to be warranted in tooling up and staffing a proper department to make aircraft parts.

That is not to say that the foundryman's art is incapable of making satisfactory castings for airframes and engines, nor that the average foundryman is a dolt or an antique. It is a safe gamble that their personnel assays as high in intelligence and honesty as any other. Within the limits of their present tools they are doing a good job — quite good enough for their bread-and-butter accounts and, as remarked above, good enough is sufficient. But when that is said it must also be remarked that the foundry's present tools and techniques are by no means perfect; in several respects means can undoubtedly be devised (if they have not already been found) for improving dimensional accuracy, surface smoothness, interior soundness and metallurgical uniformity so that the actual requirements of the air age can be met.

Note the term "actual requirements". There is no such thing as a "perfect" casting nor a "perfect" anything else. As sure as the fact that castings can be improved is the proposition that they will not be as smooth as a cold rolled sheet, as accurate as a gage block, of exactly uniform grain size in thick and thin section, and entirely free from segregated microconstituents. Equally sure is it that once the aircraft builders get to know more about the possibilities of really good castings, they will start devising parts (shapes) favorable for the casting process (just as they now habitually think of riveted fabrication), and inspectors will learn to differentiate between defects that are really damaging and minor deficiencies which can be tolerated in regions of low stress.

But here we have a dilemma: An approaching need for excellent castings by a suspicious industry and no foundry wanting to take on the thankless job of education and development! This impasse might be solved by building an excellent foundry, captive to a large aircraft fabricator; then start making castings of aircraft quality. (Precedent for this already exists in the Air Forces' "manufacturing methods pilot plant" in Michigan, largely devoted to the study of forging and extrusion.) An equally sensible allowance would be for a foundry, not an experimental foundry, but a life-sized foundry, managed by the most intelligent men that could be hired, whose duty it would be to make castings for airframes. It could start with the very best of the conventional tools and techniques and make such castings as could be made thereby, sound and of high quality. The aircraft industry could get acquainted with their virtues, thus educating itself, and get ready to design and use the really remarkable castings that could eventually be made as the foundry injected modern metallurgical science, ceramics, and mechanical engineering into its practices.

Wanted: a specialized foundry

As MIGHT BE GUESSED by one who has read this far, The Editor was impressed with the size and complexity of the castings being made into huge turbines and pumps at the plant of Pelton Water Wheel Co. in San Francisco. This firm, leader in western power plant engineering since the mid-1880's, gained its early eminence through a water wheel invented by Lester A. Pelton. It was part and parcel of the era of hydraulic mining of Californian gold-bearing gravels. His impulse turbine, so called, is exceedingly simple and practically immune to scour. Some buckets are bolted to the rim of a wheel and a stream of water at high pressure and velocity is shot against the buckets. Pelton wheels are found all over the mountainous country, ranging from little ones, 6 in. in diameter for lighting a single home, to six-nozzle combinations developing over 60,000 hp.

Fatigue where metal is thickest

To perfect the design of such equipment and

to raise its efficiency beyond 90% for loads between 20 and 90% of capacity, Pelton has its own hydraulic laboratory, completely equipped. A major tool is the use of lucite models wherein stresses can be measured and water flow observed visually and by high-speed camera. An expert supersonic testing team has also been trained, following the disconcerting discovery of some cracked turbine buckets. (This team was recently loaned to one of the power companies on the Coast and made a survey of all its high-speed machinery. It must have been comforting to read the resulting bill of good health.)

The fatigue cracks mentioned were in carbon steel castings, through 3 x 8-in. lugs straddling the wheel disk. Computed stresses were quite moderate, but in the outer element they consisted of centrifugal tension plus stress from force fits on the connector bolts, overlaid by oscillating beam tension at those instants when the water hit the bucket. In a six-jet wheel running at 300 r.p.m., it takes only nine hours to count up a million alternations. The lugs themselves are far more massive than the bucket sections; to insure soundness the foundry provided heavy sinkheads. Result — the lugs cooled slowly, contained enormous dendrites, but worst of all, segregated impurities — wonderful stress raisers. Revised melting and gating practice now insures metal of integrity at these portions, and Magnaflux, X-ray and supersonic reflectoscope prove the quality of sample castings from each heat.

Low alloy better than high alloy

NO ONE CAN DOUBT the expanding future of good castings after a visit to American Foundry and Machine Co. in Salt Lake City. As a part of Eimco Corp., makers of mining machinery, a goodly part of the castings has always been liners for ore grinding mills. For many years Hadfield's manganese steel was thought to be best for this application, in view of its great toughness and the ability of this austenitic alloy to harden superficially and automatically on impact. Unfortunately there were occasions when this expensive high alloy wore out as rapidly as the commonest carbon steel! With the help of Climax Molybdenum Co. and Battelle Memorial Institute, Eimco developed a new alloy capable of uniform hardening in heavy mass to a tempered martensite full of carbide particles — apparently a microstructure optimum for abrasion resistance.

This steel is melted in acid electric furnaces to the following composition: 1.0% carbon, 0.9% manganese, 1.5% chromium, 0.5% molybdenum. After shaking out and cleaning, the castings are heated to 2000° F., 6 hr. at temperature, for homogenization and for putting as much carbide into solution as possible. This is done in a bell-type furnace, gas-fired, whereupon the entire load, rack and all, is quenched in the biggest salt bath The Editor ever did see, a pot 12 x 12 x 6 ft. holding nearly 50 tons. Temperature is 700° F. and the salt is vigorously agitated by compressed air jets. After holding a load of castings in the bath for 5 hr. the isothermal transformation of austenite into bainite has virtually stopped, but about 75% of the austenite is retained. Substantially all of this is transformed and fine particles of carbide precipitated by a subsequent 4-hr. temper at 1150° F. (in a car-bottom annealing furnace). Hardness clear through to the center is not very high (350 Brinell) but the carbide particles with Knoop hardness approaching 1000 are much harder than quartz (Knoop 750), the hardest mineral ordinarily encountered. At any rate, this alloy, intelligently compounded and intelligently heat treated, is capable of outlasting the toughest substitute (Hadfield's) or the hardest one (Ni-Hard).

Studies on core mixtures

Don Rosenblatt, metallurgist at American Foundry and Machine Co. and past chapter chairman, has installed a complete laboratory for the study of core mixtures. (In this he believes in Harold Roast's contention — see p. 668 of this issue — that much valuable work can be done in a relatively small experimental department.) In order to avoid hot tears the cores should collapse while the casting is cooling, and "collapsibility" should vary with dimension. Of course, permeability, hot strength and compressibility are three other important properties of a good core. To vary these in proper ratio, each to each, the basic sand — clean silica particles — is compounded with addition agents like moisture, cereal bond, and resin. Rosenblatt is finding that certain phenolic resins have surprisingly large influence in governing collapsibility; a little of it goes a long way. The whole range of core sizes and metal sections they meet in their work at Salt Lake City has been subdivided into six regions and a formulation correct for each is being sought. Some have already been found. Eventually the core makers will have six specified mixes, each colored individually, each correct for size.

Here's one item where improvement is being made in conventional foundry tools — a requirement for better castings.

By Adolph Bregman
Consulting Engineer
New York City
Consulting Editor for Metal Progress

Metal Finishing of Household Equipment at Servel's Plant

METAL finishes employed by Servel fall into two classes, the entirely functional and those that are both functional and decorative. In the first group there are the copper, zinc and tin electroplates, galvanizing, zinc metallizing, and aluminizing; the second group embraces the nonmetallic coatings such as baked enamels, black and aluminized black Japans, porcelain enamel and "plastic coatings". In addition, a number of surface treatments are employed either as a preparatory step for the subsequent surface coating or as a corrosion preventive process.

Servel, Inc., Evansville, Ind., is one of America's leading manufacturers of household devices for refrigeration and air conditioning. In one important aspect, however, Servel differs from other manufacturers of such equipment — its products rest primarily on the use of gas as a fuel. Some electrical equipment is made to special order, but this forms only a small part of their total output.

The products of Servel are household refrigerators, household water heaters, gas or steam operated "All-Year" air conditioners for cooling air in summer and heating air in winter, and cooling towers to be used with the air conditioners if the water must be conserved. The company also makes an electric ice cube maker, and electric refrigerating units up to five-ton capacity which are sold to other manufacturers and go into other products than Servel.

Servel is the only gas refrigerator currently on the market. Its unique feature is that it contains no moving parts, being made entirely from steel tubing, formed and welded or brazed to make up the assembly. An interesting example of this type of work is a steel coil, coated with aluminum and brazed to an aluminum freezer shelf. Of this part, more will be said later.

The magnitude of the operations of the company may be judged from the fact that the Evansville plant occupies about 1,400,000 sq.ft. and employs about 6000 people at this time. It is interesting to note that the finishing departments cover about 135,000 sq.ft. and employ about 500 people, approximately 10% of both the total floor space and employees.

Metal Finishing Operations

The metal finishing operations used in connection with Servel equipment may seem to be only a small part but, even though they comprise only about 10% of the total, they are a very critical 10%. Without properly chosen and skillfully applied finishes, the product would be both unworkable and unsalable. Nonmetallic finishes are both functional and decorative, their purpose being corrosion- and leak-prevention and attractive outside appearance. The electroplates are almost entirely functional in character, their main purpose being protection against corrosion.

The following types of operations are included in the metal finishing departments:

1. "Painting" or coating with a variety of nonmetallic finishes, including baked gray enamel, baked white enamel, baked black Japan and baked aluminized black Japan.
2. Porcelain enamel.
3. Special abrasion resistant syn-

thetics ("plastic coating") for shelves.

4. Aluminum treatment, anodizing to a matte finish or high luster.

5. Zinc plating on food shelves as an undercoat for plastic coating.

6. Phosphate coating as an undercoat for enameled or painted surfaces.

7. Decorative plating on outside parts, hardware, etc., mainly copper, nickel and chromium on die castings. This plating is not done by the company but is furnished to them on parts made by outside vendors.

8. Hot galvanizing.

9. Sprayed zinc coatings.

10. Aluminum coating on steel coils.

The importance of metal finishing in the Servel plant may be judged from the large number of parts and the variety of operations covered by protective or decorative coatings.

Several small parts are covered with a special plastic coating. These shelves are first electroplated with zinc and then pretreated in dip tanks containing a phosphate priming coat of the Bonderite type before the application of plastic coating. Conveyers carry the shelves through tanks and Ransburgh electrostatic detearing equipment and into the baking oven.

A substantial amount of prepolishing of small parts to prepare them for subsequent plates or nonmetallic coats is done in tumbling barrels made by Globe Stamping Div., Hupp Corp.

Brackets and other odd parts are plated with zinc for purely protective purposes and later coated with baked enamels. The evaporator gas heat exchanger assembly is hot dip galvanized. Sheet steel icemaker cabinet sections and water heater exterior parts are coated with a sprayed white enamel. Copper water heater parts are bright dipped using Ferrisul (anhydrous ferric sulphate).

An important department for the preparation of metals for subsequent finishes of any kind is the blast cleaning installation which uses sand as the cleaning medium. This will be described in some detail later.

Aluminized Black Japan

An interesting finish used by Servel is the aluminized black Japan that is sprayed on a special coil and plate assembly for added protection to the aluminum coating which lies underneath. The addition of aluminum to the black Japan results in a brown or mahogany colored coat on baking. As applied to the refrigerating mechanism of the household unit, the cycle consists of *(a)* spray wash, *(b)* blowing off excess water, *(c)* drying in oven, *(d)* cooling, *(e)* black Japan, applied by dip; or alternatively, an aluminum paint spray, and *(f)* baking. An important advantage of the heavy black Japan coat which is applied to the unit is its ability to seal all openings, rendering the equipment leak-proof in later service.

An interesting device is employed in finishing the refrigerator unit. This unit includes a fuse pipe, which melts at 300° F., to prevent overheating and burning out of the unit. When the fuse melts, the circuit is broken and damage is averted. However, this fuse pipe is part of the assembly which goes through the Japan baking furnace and would, under ordinary circumstances, melt in the baking operation. Therefore, an ordinary tin can filled with water is set in the assembly so that the pipe dips into the water which maintains it below its melting temperature for the 30 min. required for the baking operation. The water-filled can is then removed and the assembly continues to move progressively on the line.

Enamels and Metallic Finishes

White enamel for the refrigerator cabinet exteriors is applied by automatic spraying in a conveyer setup with the Ransburgh electrostatic spray equipment. This finish is also applied on Panelyte door liners which are made of a nonmetallic of the Bakelite type. Servel's practice is to add a small amount of carbon to the material used in the Bakelite-type liner to make it conductive and thereby take the electrostatic spray. A continuous water wash recovers the enamel from the overspray. The work is handled by conveyer through the spray and bake as well as through the phosphate coating treatment tanks before the paint is applied. The complete cycle consists of *(a)* cleaning, *(b)* phosphate coating, *(c)* applying prime coat of enamel, *(d)* baking, *(e)* applying top coat of enamel, and *(f)* baking.

The porcelain finish is a clear white. Frit is purchased from outside, then ground and mixed in the plant to form a dip which is applied at room temperature. The parts are moved through the cleaning and precoating operations, through the ground coat, through the finish coat spray booth and then through the baking oven, all by conveyer.

Pretreatment of parts to be vitreous enameled consists of cleaning, rinsing, pickling, rinsing, a nickel dip and drying. (The nickel dip contains nickel salts in the amount of 1 to 1½

oz. per gal. of de-ionized water.) Acidity is maintained at pH 3 to 4 with the use of sulphuric acid or flake caustic soda.

Dip Bonderizing (the preparatory undercoat for many of the nonmetallic finishes) is followed by two coats of gray paint with bakes between the paint coats and, of course, the necessary rinses and cleaners before and after the Bonderizing operations.

A number of parts are given either a zinc, tin or copper electroplate. Zinc plate is applied in a cyanide solution (Du Pont Durobrite) on food shelves to form a base for the later top plastic coat. This is followed by Bonderizing and the plastic finish which is applied on the Bonderized zinc coat. The zinc plating is done in a fully automatic plating setup made by Lasalco, Inc.

Zinc plating of internal hardware, braces and brackets is done in Lasalco barrel platers and in still tanks made by Servel. These items are then bright-dipped in a ½ to 1% nitric acid solution. Tin plating is performed in stannate baths on copper thermostat parts for corrosion protection. Copper plating is confined to stop-offs for cyanide heat treatment and applied in the conventional sulphate solution. The plating department uses General Electric Co. rectifiers and controls, and Columbia Electric Co. and Hanson-Van Winkle-Munning Co. generators.

Special Assembly Operations

Steel fittings are copper-brazed to the steel dome for the electrical refrigeration compressor units. A conveyer moves the parts through the furnace. Copper brazing is performed on the condenser parts which are made of Bundy tubing. This brazing operation also is handled by conveyer. Silver solder is applied by hand torch to the copper and brass fittings on the dome for the electric refrigerating units.

The ice tray grid of the ice cube maker is made of copper, coated with hot dipped tin for protection. The copper is used because of its high heat conductivity. Another conveyerized operation is the thermostat assembly which requires silver brazing of the copper tubing.

One of the most important factors in the manufacture of Servel products is the prevention of leakage of refrigerants. The inspection equipment is, therefore, very accurate. For example, one of these machines is a mass spectrometer leak detector which is used to check air conditioners. This spectrometer detects leaks so small that it would require 10,000 years of leakage to fill a quart bottle.

A Selas gas brazing unit is used to assemble the evaporators for the air conditioners. The evaporator employs 36 copper tubes brazed to sheet steel heads at each end, to form an assembly 34 in. long.

One of the current problems in the manufacture of refrigerators is attaching the tubing

Fig. 1 — Welded Coil Units Are Conveyed Into Air Blast Room Where Weld Junctures Are Cleaned by Three Air Blast Units in Preparation for Zinc Metalizing. This "spot plate" eliminates the necessity of redipping the whole assembly

for carrying the liquid refrigerant to the light-gage sheet used for shelves. J. A. Woolrich in his discussion "Aluminum Brazing" in *Metal Progress* for February 1950, p. 217, reports one instance where aluminum is used throughout, the assembly being made by continuous furnace brazing. At Servel, however, the freezer shelf coil is of steel, protected from corrosion by a coating of aluminum.

Previously, Servel had used extruded aluminum shelves formed around the steel coils. In 1950 the Servel refrigerator assembly was changed to take advantage of a new process which permits the steel coils to be coated with aluminum and then brazed to the aluminum shelf in one operation. This unit provides better heat transfer resulting in better refrigeration. Also, the cost of manufacture is reduced.

Sandblasting Replaces Pickling

The preparation of the steel coils and aluminum shelf for aluminum coating and brazing is done by sandblasting in a 14-ft. LG Pangborn airless, centrifugal-type Rotoblast, replacing pickling and other methods of surface preparation previously employed. This table is also used to prepare other small parts prior to assembly. The table completes the sandblasting operations in two passes through the blast stream, at a speed sufficient to keep three operators busy loading, unloading and turning the pieces. The evaporator coils, gas heat exchanger assemblies and other items to be blasted are handled by automatic conveyer.

Another instance involves hot galvanized coil units which have been welded together for final assembly. At the juncture of these welds the previously applied zinc coat has been destroyed by the welding operation. It is necessary, therefore, to clean the steel coil surfaces and then recoat these points with sprayed metallic zinc to prevent corrosion. For this blasting operation, a blasting room is used which is equipped with a monorail-type conveyer and three standard Pangborn AC-3 airblast units. The welded tubing is conveyed into the air blast room where it is "spot blasted" by three operators, each in an individual compartment with an individually controlled hose blast machine. Still moving, the blast-cleaned tubing moves through the room to the metallizing station where zinc wire, acetylene and compressed air are used to "spot plate" where needed.

An interesting part of the sandblasting operation is the so-called "pencil" sandblast applied by a hand spraying tool similar to the gun used for nonmetallic spray finishes. This pencil sandblast is applied to any defective spots which may appear in the porcelain-coated cabinet liners, blasting out the defective areas. The parts are then recoated and run through the cycle again. The savings effected by this method of reclamation and reduction of rejects are obvious.

Control, Testing and Research

Laboratories constitute an indispensable part of the plant organization. In addition to the chemical, metallurgical and metallographic laboratories the company has also electroplating and new paints laboratories. The electroplating laboratory runs beaker-size trials, Hull cell tests and solution analyses. The paint laboratory completely tests all the properties of paint films. These tests cover: Hardness, flexibility, weathering by machine and sun exposure, moisture (water soak and humidity), color control, cryptometer, specific gravity, viscosity, as well as resistance to impact, abrasion, grease, fumes and stain.

The engineering department is charged with the responsibility of running control tests on new enameling materials and shipments of material. It conducts mill, dip, spray, and fire tests on shipments and new materials; reflectance, acid resistance, tearing and hairlining tests on fired samples; and hardness and flow tests on frit. Process control of enameling is the responsibility of the production department and this covers *(a)* solution control for metal preparation, *(b)* firing check on milled enamel, *(c)* dipping and spraying controls by specific gravity and pickup or viscosity tests.

By maintaining careful control of every phase of metal finishing, a high degree of economy is achieved in the application of the coatings, together with good quality.

Fig. 2 — A "Rotoblast" Table Is Used to Prepare Steel Coils for Aluminum Coating and for the Cleaning of Other Small Parts Prior to Assembly. About 85% of the work is now cleaned by this method

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Cost of Welding Stabilized Stainless

Titanium or columbium is commonly added to chromium-nickel stainless steels in sufficient amounts to combine with all the carbon present, thus preventing the precipitation of chromium carbide at the grain boundaries on heating in the range of 800 to 1500° F., and so avoiding the resulting susceptibility to intergranular corrosion. Of the two stainless steel grades, A.I.S.I. Type 321 (titanium stabilized) steels exhibit some superior attributes when compared to the A.I.S.I. Type 347 (columbium stabilized stainless steels). Many of these advantages were admirably discussed at some length in the November 1950 issue of *Metal Progress*.

The investigation now to be described concerns itself only with the welding characteristics of stabilized stainless sheet. Corrosion properties of welded Types 321 and 347 stabilized grades with various heat treatments in various commercial environments were compared by George Comstock in Special Technical Publication No. 93 of the American Society for Testing Materials. The effects of heat treatment and composition as related to corrosion rates in a specific medium, namely, boiling nitric acid, have also been described by R. S. Stewart in *Metal Progress* for December 1947. Work on high-temperature properties of Type 321 conducted during the last six years at the University of Michigan is currently being summarized and will be published in the near future. Each of these studies demonstrates the ability of Type 321 to retain its corrosion resistance after many varieties of exposure to high temperatures.

In addition to the foregoing, welding tests have now been made and costs evaluated for both Type 321 and 347 stabilized stainless sheet. Inert arc and the metallic arc welding processes were used. The analysis of the 18-g. sheet used in this investigation is as follows:

	Type 321	347
Carbon	0.07%	0.05%
Manganese	1.30	1.62
Phosphorus	0.022	0.030
Sulphur	0.009	0.012
Silicon	0.48	0.29
Chromium	17.74	17.12
Nickel	9.98	11.11
Titanium	0.56	—
Columbium	—	0.76

The results, now to be summarized, clearly show the means by which more satisfactory and more economical weldments can be made from Type 321 sheet than from Type 347 sheet. The phenomenal welding speeds which may be attained with Type 321 steel substantiate the recent work of John F. Tyrrell who investigated resistance, gas, metallic arc, and inert arc welding processes (see *Metal Progress*, July 1950).

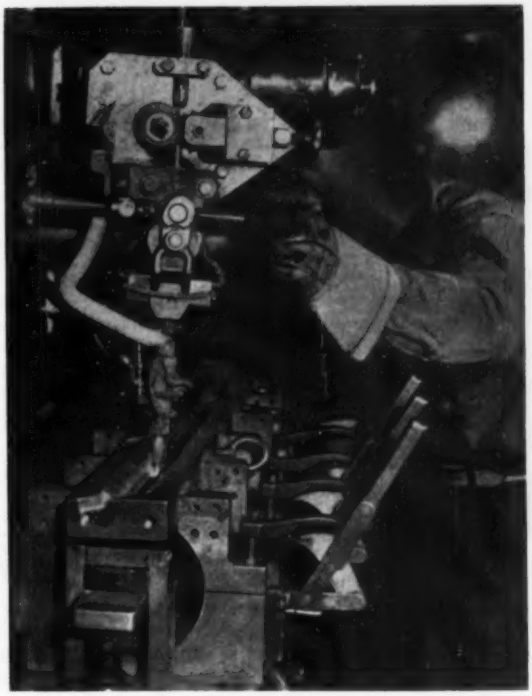
Inert Arc Welding — A total of one 36-in. and nine 24-in. welds was made of Type 321 sheet using both a Type 321 welding rod and a turned-up edge or butt weld with no filler rod. It was considered irrelevant to make comparative tests on Type 347 sheet with inert arc because of its excessive cost. To prepare the metal for welding, a slightly flared or turned-up edge, produced in shearing the sheet, proved quite adequate. Welding may also be performed by butting flat Type 321 sheets and using Type 321 bare wire as a filler rod, although this may cut down optimum welding speed.

Argon was used as the inert atmosphere rather than helium because experience in numerous shops has shown that the behavior of the torch is much more satisfactory with argon by virtue of its better conductivity.

Results of the inert arc welding tests are contained in Table I, and show that the maximum welding rates with good penetration and sound welds of Type 321 sheet are as follows:

1. With turned up edges: 80 to 85 in. per min. may be attained with 175 amperes.

2. The same speed can be attained for flat sheared sheets, employing a filler rod, provided the operator develops sufficient manual dexterity in the manipulation of the rod.



The only significance of the tungsten electrode size is that the greater the speed of welding, the greater must be the current. The higher currents necessitate the use of larger electrodes.

Though this study did not compare the inert arc welding speeds attainable of Types 321 and 347 stainless sheet, such comparisons have been made by Mr. Tyrrell in the article above mentioned, and he has amply demonstrated that Type 321 can be inert-arc welded at much higher welding speeds than can Type 347 without cracks developing at the weld zone.

Metallic Arc Welding — A total of 26 welds was made of Types 321 and 347 sheet, using either coated or bare Type 347 welding rod. Results are tabulated in Table II, p. 652. Although bare Type 347 welding rod produced superior welds at faster speeds than the coated Type 347 rod, these results are not shown, since it is not considered good technique to weld stabilized sheet with an uncoated rod. Furthermore, the welds were not evaluated for corrosion resistance—which would favor the welds with coated rod.

Preliminary trials gave evidence that it is imperative that the sheet edges are flush (minimum gap between sheets to be welded), to prevent "burn-away". To attain this desired set-up the sheets should be held in a suitable clamping fixture.

To obtain the optimum welding speeds with sound welds, both speed and current input were varied and the results recorded. As indicated from Table II the optimum conditions for metallic arc welding 18-g. stabilized stainless sheet are as shown in the following tabulation:

Sheet Type	Rod Type	Welding Speed In. per Min.	Heat Input (Amperes)
321	Coated 347	30 to 35	75 to 80
321	Bare 347	35 to 40	75 to 80
347	Coated 347	25 to 30	85 to 95
347	Bare 347	30 to 40	90 to 100

Higher welding rates yield poor penetration; higher heat inputs give a burn-away condition. Either of these would be considered inadequate.

Straight polarity in contrast to reverse polarity is recommended for best results. Also the length of the welds for results obtained varied from 10 to 36 in., with the distance traveled having no effect on the resultant weldment.

Only a slight difference in welding speeds

Table I — Speed (In. per Min.) of Inert Arc Welding of 18-G. Type 321

Rod	Speed	Electrode	Current	Penetration	Speed	Heat	Weld
None*	8	1/50 in.	60 amp.	Good	Too low	—	Good
321	8	1/50	60	Good	Too low	—	Good
None	75	1/16	160	Good	Too low	—	Good
321	35	1/16	140	Good	Too low†	—	Good
None	120	3/32	200	Incomplete at end	Too high	Limiting	Fair
321	75	3/32	175	Good	At limit†	—	Good
None	86	3/32	175	One bad spot	At limit	—	Good
None	85	1/16	150	Fair	—	Insufficient	Fair
None	75	1/16	160	Good	Optimum	Note *(a)*	Good
None	80	3/32	175	Good	Optimum		Good

*Butt-type weld performed with slightly flared edges.
†Difficult for operator to feed weld rod at this or faster rate.
(a) Use higher heat with larger electrode, as in next line.

Table II — Metallic Arc Welding, Type 321 Versus Type 347 (3/32-In. Coated Rods, Type 347)

Sheet	Speed	Current	Polarity	Penetration	Speed	Heat	Weld
321	30 *(a)*	75 amp.	Straight	Good	Too low	Satisfactory	Good
321	35	75	Straight	Incomplete	Maximum	—	Fair
321	45	75	Straight	Insufficient	Too high	—	Poor
321	60	90	Straight	Insufficient	Too high	Too high*	Poor
321	30	75	Reversed	Fair	—	—	Good
347	60	100	Reversed	Insufficient	Too high	Too high*	Poor
347	40	80	Reversed	Insufficient	Too high	Too low	Poor
347	85	100	Reversed	Insufficient	Too high	Too high	Poor
347	40	85	Reversed	Insufficient	Too high	Satisfactory	Poor
347	50	80	Reversed	Insufficient	Too high	Too low	Poor
347	35	80	Reversed	Fair	Too high	Satisfactory	Fair
347	30	70	Reversed	Poor	—	Too low	Fair
347	30	80	Reversed	Fair	Slightly high	Slightly low	Fair
347	30	100	Reversed	Good	—	Slightly high*	Fair
347	25	85	Reversed	Good	Optimum	Optimum	Good *(b)*
347	25	85	Straight	Good	Optimum	Optimum	Good *(b)*

*Burn-away condition noted. *(a)* Inches per minute. *(b)* The weld with straight polarity is slightly better.

can be noticed between sheets of Type 321 and Type 347; however, the major difference comes about through the cost of the sheet, as will be shown later.

Tensile tests were made with each weldment at the center of the test piece. Results showed that those welds with good penetration did not break at the joint. For the sake of brevity, these results are omitted.

Cost Evaluation

For the purpose of evaluating costs, the complete welding of the entire periphery of a standard 18-g. sheet, 36 by 120 in. in dimension, or 312 in. of welding, was considered. The calculated values do not account for set-up time, which would be uniform for both types of sheet. Material costs were quoted by a large producer of stainless steel on the basis of a No. 1 or hot rolled finish.

Labor costs in Table III include both direct and indirect, including overhead in the locality where the welding was performed. The labor cost for inert arc welding of Type 321 sheets is calculated by using an average speed of 80 in. per min. with a slightly turned-up edge. Argon costs average 9¢ per cu.ft., or $21.40 per cylinder. At the rate of 10 liters per min., one cylinder should last for 16 hr. of continuous welding, or a cost of $1.34 per hr.

Labor costs for arc welding were calculated using the following optimum speeds:

1. Welding Type 321 sheet with coated rod: 32 in. per min.
2. Welding Type 321 sheet with bare rod: 37 in. per min.
3. Welding Type 347 sheet with coated rod: 25 in. per min.
4. Welding Type 347 sheet with bare rod: 35 in. per min.

Table III — Estimated Cost of Welding Around a 36 x 120-In. Sheet of 18-G. Stainless

	Type 321 Sheet			Type 347 Sheet	
Rod	None*	347 coated	347 bare	347 coated	347 bare
Cost of sheet	40.95	40.95	40.95	43.79	43.79
Cost of gas	0.09	—	—	—	—
Cost of rod	—	0.40	0.25	0.40	0.25
Labor†	0.26	0.64	0.56	0.83	0.59
Total	$41.30	$41.99	$41.76	$45.02	$44.63

*Inert arc welding. †Set-up disregarded.

Conclusions

From the data obtained, it is evident that Type 321 (titanium stabilized) stainless sheet may be purchased and welded with superior welds at less expense than the cost of the Type 347 (columbium stabilized) stainless sheet alone. This is true for either process, inert arc welding or metallic arc welding, although the inert arc welding process yields joints with higher strength and is cheaper to perform than the metallic arc welding, its greater economy being possible by virtue of the faster welding speeds safely obtainable.

Reported by
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High-Temperature Steels and Alloys for Gas Turbines

WHEN the war ended, it was generally accepted in England that the gas turbine would be the engine for many future types of aircraft, and it was widely expected that prime movers of this kind would also have important land and marine applications. Also, it was universally recognized that progress in gas turbines of all kinds would depend on the metals made available for use in them. Since then, aircraft gas turbines have developed rapidly, and efficient and reliable units of many designs are now being made in large numbers.

Development of such engines with even higher thermal efficiency introduces difficulties with regard to constructional materials capable of withstanding and operating at increasingly high temperatures, and to gain a cross section of the work carried out on this subject in the past decade, the council of the Iron and Steel Institute decided to organize a "Symposium on High-Temperature Steels and Alloys for Gas Turbines". This symposium was held in London on Feb. 21 and 22, when some 40 technical papers were presented by members of the Institute and discussed by Britishers and their guests from all over the world.

On the evening prior to these sessions, Sir Frank Whittle, British pioneer of jet engines, delivered the fifth Hatfield Memorial Lecture to a cosmopolitan audience of over 650, when he spoke on "Turbine Problems in the Development of the Whittle Engine". He paid eloquent tribute to the part played by the late Dr. W. H. Hatfield of Sheffield and his colleagues in the development of certain steels which eventually made the first engine possible. He also traced the progress of the jet engine to the present day, dwelling mainly on the engineering aspects that were encountered and solved.

D. A. Oliver, director of research, B.S.A. Group of Companies and chairman of the organizing committee of the symposium, acted as chairman of the opening meeting. He first apologized for the postponement of the symposium from last fall, owing to the printers' strike which prevented the papers from being fully preprinted and circulated. This had caused one American delegate, Howard C. Cross, metallurgist at the Battelle Memorial Institute, to cross the Atlantic twice in a relatively short period of time! Pointing out that the papers were exclusively by his countrymen, he said discussion would be especially welcome from abroad. Part of the work of the past 10 years had hitherto been veiled for security reasons.

The papers presented fall into six groups: 1. User's point of view, including three papers by firms engaged in the construction of gas turbines. 2. Nickel-base alloys, and austenitic and ferritic steels now being produced in Britain. 3. Six papers on the properties of high-temperature materials, such as scaling, high-temperature fatigue, and variation in elastic modulus. 4. Seven papers on manufacturing techniques, such as centrifugal casting, precision casting, welding and machining. 5. Research techniques. 6. General developments in sintered metal and ceramics. A *rapporteur* gave a résumé of each group of papers, whereupon a general discussion occurred before attention was given to the subsequent group.

Appropriately enough, the leading paper in the symposium was an introduction by N. P. Allen, superintendent of the metallurgy division of the National Physical Laboratory, entitled "A Survey of the Development of Creep Resisting Alloys", and the final paper was "Future Needs in Materials for Land and Marine Gas Turbines"

by J. M. Robertson, chief research metallurgist for C. A. Parsons & Co., Ltd. Dr. Allen's masterly historical summary, a condensation into ten pages of printed text, viewed British, American and German developments up to 1946. The history is one not of revolutionary discoveries but of short advances, each one leaning upon knowledge gained elsewhere; no new practice arose in one place alone. In general, the alloys of 1946 have properties at 1500° F. comparable with those of the 1938-alloys at 1200° F.— largely by taking advantage of alloying additions which conferred the property of precipitation hardening. He emphasized that these 1946-alloys were for short-lived engines for aircraft; the bulk of the papers in the symposium consider materials for larger engines of much more durability.

Table I — Creep of Double Aged Nimonic 80 at 650° C. (1170° F.) and 33,750 Psi.

21.4% Cr, 2.34% Ti, 0.38% Al, 3.08% Fe, Balance Ni. Solution treated 8 hr. at 1080° C. (1975° F.) and water quenched. Hardness 189 to 200 Vickers diamond.

Aging Treatment	Hardness	Secondary Creep Rate	Time to Onset Tertiary Creep	Time to Fracture
16 hr. at 700° C.	329	0.0060% per hr.	70 hr.	111 hr.
2½ hr. at 800° C. plus 16 hr. at 700	327	0.0005	230	248
½ hr. at 850° C. plus 16 hr. at 700	315	0.0013	260	283

Ni-Cr-Ti Alloys

The leading examples of the nickel-chromium-titanium family are the "Nimonic" alloys. L. B. Pfeil, manager of the development and research department of Mond Nickel Co., Ltd., and his former associates N. P. Allen and C. G. Conway, gave information on the Nimonic 80 type of alloys. This contains 18 to 21% chromium, 2 to 2½% titanium, approximately 0.5% aluminum, the balance being nickel. In the development of the series, it was found that some melts hardened considerably during air cooling, and it was thought that for some machining operations this would be objectionable. Experiments were therefore carried out to see whether the loss in creep properties associated with water quenching from the solution heat treatment could be neutralized by modifying the subsequent aging treatment. Some of the results are set out in Table I. By the application of a double aging treatment, involving a short preliminary aging at 800 to 850° C. (1500° F.), followed by a prolonged aging at 700° C. (1290° F.), the ill effects of water quenching on the secondary creep rate, on the time to onset of tertiary creep, and on the time to rupture, could be overcome.

Since this paper by Pfeil, Allen and Conway was written, Mond Nickel Co. has released details of a still newer alloy, Nimonic 90, with increased creep strength. At 750° C. (1380° F.) Nimonic 80A is required to withstand a stress of 38,000 psi., and Nimonic 90 a stress of 42,500 psi. At 815° C. (1500° F.) and even 870° C. (1600° F.) Nimonic 90 has shown high load-carrying capacity for long periods. It can be forged between 1050 and 1150° C. (1920 and 2100° F.), although it rapidly stiffens below this temperature.

Electro-Machining — These high nickel-chromium alloys, akin to the 80-20 electrical resistors well known to Americans as Nichrome or Chromel, rapidly build up a protective scale when heated in air. This scale is extremely thin, but oxide may penetrate grain boundaries to perhaps 0.003 in. and produce an undesirable notch effect in parts working under alternating stresses. It can be completely removed by "electro-machining", a process similar to electro-polishing, wherein the part is made anodic with suitably disposed cathodes in a 50% HCl solution and 0.8 to 1.5 ampere per sq.in. current density. After 5 min. the part is removed, lightly shot blasted to remove adherent oxide, and again immersed for 5 min.

Dr. Pfeil also notes the importance of short-time acceptance tests for commercial heats. His experience is that, if the analysis is correct and the metal works properly in forging, the heat will be up to standard if it follows a normal strain-time curve in a short creep test. In the latter sense, the British standard D.T.D. specification No. 736 for Nimonic 80A calls for a secondary creep rate not exceeding 0.01% per hr., time to onset of tertiary creep not less than 50 hr., and time to rupture not less than 75 hr. under stress of 38,000 psi. at 750° C. (1380° F.).

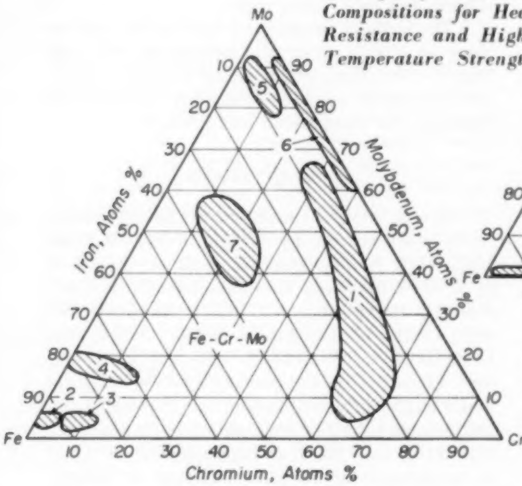
Chromium-Base and Cobalt-Base Alloys

E. A. G. Liddiard and A. H. Sully, of the Fulmer Research Institute (Stoke Poges) reviewed the methods of producing chromium-base alloys, wherein difficulties are encountered in all methods designed to remove oxygen from the metal and to prevent further contamination

by oxygen, nitrogen, or carbon. It appears that melting and casting operations should be carried out in a vacuum or in an atmosphere free from these elements.

Certain chromium-base alloys possess a very high level of creep resistance at 900 to 1000° C. (1650 to 1830° F.) and are believed to be superior to any other metallic alloys so far investigated in this range of temperature. They also have high resistance to oxidation and a fairly low density. Unfortunately, chromium and its alloys have extremely low ductility at room temperature. Their applicability to gas turbine construction would be much widened if their ductility at normal temperatures could be significantly improved.

Fig. 1 (Left) — Suggested Areas of Useful Fe-Cr-Mo Compositions for Heat Resistance and High-Temperature Strength



According to J. C. Chaston and F. C. Child of Johnson Matthey & Co. Ltd. (Wembley), the tantalum-chromium-cobalt alloys appear to offer promise, especially for service as castings at temperatures around 900° C. (1650° F.). The alloy containing 10% Ta, 10% Cr, and 0.3% C has been selected for special study and has been cast successfully by the usual precision casting technique. If maximum creep endurance is required, it would probably be advantageous to increase tantalum and chromium contents to 15% or more.

Ternary

The phase relationships of the iron-chromium-molybdenum and iron-chromium-tungsten systems have been investigated by H. J. Goldschmidt of the B.S.A. Group Research Center (Sheffield). Their method consisted of synthesizing small samples by mixing appropriate powders, compressing and sintering at 1400° C. (2550° F.) for 16 hr. to permit interdiffusion, then annealing the compacts at 620° C. (1150° F.) for 60 hr. for a low-temperature equilibrium. The resultant small sinters were then studied by X-ray diffraction methods to determine the constituents and their lattice dimensions.

Results are given in a pair of triangular diagrams, from which it appears that the behavior of the sigma and xi phases is largely competitive; they tend to inhibit each other. A ternary compound occurs in the iron-chromium-molybdenum system, of approximate composition Fe_4CrMo_2. The compound FeMo existing above 1180° C. in the iron-molybdenum binary is retained by quenching, and it possesses the sigma structure; it forms a continuous series of solid solutions with FeCr and, in contrast to the latter, is stable up to its melting point. Two other ternary diagrams are presented (Fig. 1 and 2) which map the approximate areas where practical application for heat resisting materials of high-temperature strength of the alloy systems may be expected, either as massive articles or as surface layers.

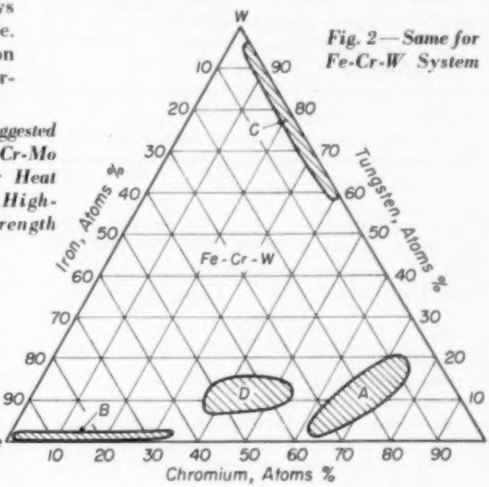


Fig. 2 — Same for Fe-Cr-W System

Creep Resisting Ferritic Steels

E. W. Colbeck and J. R. Rait, of Hadfields, Ltd. (Sheffield), describe in detail the development of a series of steels called H.G.T.3, based on 3% chromium and containing about 0.55% each of molybdenum and tungsten, about 0.75%

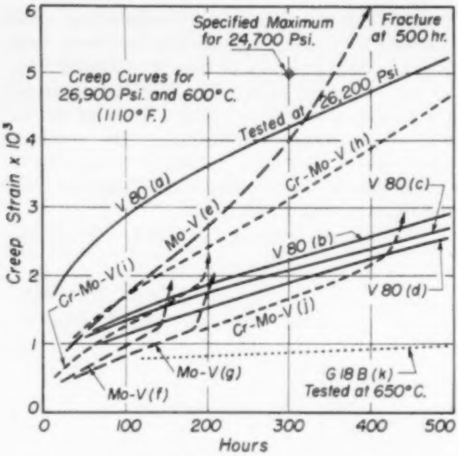


Fig. 3 — Comparative Creep Curves for Ferritic Steels Tested at 26,900 Psi. and 600° C. (1110° F.). Compare warm worked high-alloy austenitic G18B tested at 50° C. higher temperature

Legend

(a) V80 disk (boss), 127,000 psi.
(b) V80 disk (boss), 140,000 psi.
(c) V80 disk (rim), 131,000 psi.
(d) V80 disk (rim), 151,000 psi.
(e) Mo-V disk (rim), 121,000 psi.
(f) Mo-V water quenched, tempered, 131,000 psi.
(g) Mo-V oil quenched, tempered, 131,000 psi.
(h) Cr-Mo-V disk (rim), 139,000 psi.
(i) Cr-Mo-V bloom, 151,000 psi.
(j) Cr-Mo-V, 127,000 psi.
(k) G18B warm worked disk

vanadium, and 0.25% carbon. Their results so far obtained on high-chromium alloys confirm and emphasize the importance of the conclusions arrived at for the low-chromium alloys — namely, that for good creep resistance it is essential to obtain the minimum amount of a stable cubic carbide of the NaCl type, as finely dispersed as possible. While putting the carbides in this condition it is important to avoid the formation of delta ferrite, and also to avoid changes in composition of the ferritic solid solution which would weaken it.

A series of ferritic alloys containing up to 3% of chromium, with less than 1% each of tungsten, molybdenum and vanadium, has proved to have very good properties. Steels with 10 to 12% chromium can also be produced with a good combination of creep, scaling, and corrosion resistance.

Forged disks made from a steel of the same type manufactured by another firm under trade name V80 were studied by Messrs. Burton, Russell and Walker of English Steel Corp. ("Ferritic Steels for Gas Turbines"), and compared with two other ferritic steels of even lower alloy content. (See Fig. 3.) The Mo-V steel contains 0.20% C, 0.60% Mo, 0.30% V, and has been used extensively in high-pressure steam turbines. The Cr-Mo-V steel is under development and contains 0.60% chromium in addition to those just listed. All of the V80 samples are well below the specified 0.5% creep in 300 hr. under 24,700 psi. at 600° C. (1110° F.). Heat treated Mo-V steels had low creep rates but quite short lives, as was also true of the Cr-Mo-V steel bloom with high tensile strength (151,000 psi.) which started on the tertiary creep leading to failure at about 400 hr. Work is progressing on these low-alloy steels to determine optimum manufacturing conditions and heat treatments.

The authors emphasized that curves, such as those in Fig. 3, cross and recross in the early stages — less than 50 hr. — and therefore short-time properties such as frequently specified are valueless for comparison and evaluation.

Austenitic Alloys

Among several analyses of heat resisting steels manufactured by William Jessop & Sons, Ltd., G18B was selected for detailed discussion by D. A. Oliver and G. T. Harris of the firm's research organization. G18B is an austenitic alloy of the following type: 0.4% C, 0.8% Mn, 1.0% Si, 13.0% Ni, 13.0% Cr, 2.5% W, 2.0% Mo, 3.0% Cb, 10.0% Co, balance (54% ±) Fe. In their paper entitled "Some Proven Gas Turbine Steels and Related Developments" the authors point out that G18B was the first high-temperature alloy to incorporate appreciable additions of columbium and cobalt to the expected alloys nickel, chromium, tungsten, and molybdenum, and was unique in utilizing large quantities of complex carbides (reflected in its carbon content of 0.40%) when most alternative contemporary austenitic alloys had less than 0.15% carbon. It has a good balance of properties between scaling resistance, creep strength, hot and cold fatigue strength, ductility, freedom from embrittlement, and weldability.

"Warm Working" — The very earliest disks in G18B tended to stretch when speeding up from the cold, because of its deficient proof stress (31,500 psi. at 0.1% strain); radial growth on typical disks about 12 in. in diameter was as much as 0.100 in. It was found desirable to age the solution-treated disks in order to raise the proof stress by about 30%, which reduced the growth to about 0.050 in., *(Continued on p. 690)*

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Instrumentation in Steelmaking

THE PITTSBURGH section of the Instrument Society of America held its first regional conference late in March, cosponsored by the local groups of eight other national engineering societies, including the ●, and by Carnegie Institute of Technology. Its general topic was "Instrumentation in the Iron and Steel Industry". Those papers that had to do with production instrumentation in the openhearth shop will be summarized in what follows. Equally important discussions on inspection and gaging are crowded out of this account by space limitations; they will eventually be published by the Instrument Society of America.

Martin J. Conway, consulting engineer of Wheeling Steel Corp., considered "Instrumentation and Control in the Utilization of Mixed Fuels and Oxygen in Openhearth Furnaces". In an 11-furnace shop the original size of heats was 60 net tons. They are now operating at 175 net tons. These furnaces are fully instrumentalized with automatic reversal, fuel-air ratio control with correction for combustion oxygen when used, automatic furnace pressure control, and all necessary fuel meters. Both tar and oil are available for these furnaces, as well as surplus coke oven gas on week ends. Fuel input control is automatic, in that the B.t.u. per hr. input is automatically maintained whether the fuel is liquid or gaseous.

A relatively new innovation has been incorporated into the instrumentation. This is viscosity control of the liquid fuel. According to Mr. Conway, it is important that the viscosity be maintained constant so that when the liquid fuel is atomized by steam there will be no variation in flame characteristics which might otherwise be due to viscosity fluctuation of the fuel. The orthodox manner has been to control the fuel temperature. Since there is an appreciable variation in viscosity of different oils, particularly at temperatures of around 200° F., this does not assure a constant viscosity. Also, since the fuel oils used in openhearths generally are of the No. 6 heavy residual petroleum type, consumers cannot be assured of uniform quality, particularly during times of accelerated market demands and shortages. Therefore, this relatively new instrument has been developed by the Fisher-Porter Co. When this automatic control is operated through a standard liquid fuel heater, using steam for heating, a viscosity of about 150 Saybolt Universal, seconds, can be maintained at the openhearth burner atomizer.

Edward H. Cauger, also of Wheeling Steel Corp., gave some further information on this general subject. Their oxygen plant is in full use, producing 132 tons per day, 120 tons at 95% purity. Some of this is used in the recently instrumentalized openhearth furnaces. The remainder of the oxygen plant production is at 99.5% purity and is used principally for welding and scarfing. Increase in production from these 21 instrumented furnaces is extremely gratifying, together with a 15% lower fuel consumption than that obtained in 1949. Roughly, the gains in tonnage were attributed as follows: About 15% to the use of oxygen for metallurgical purposes (that is, for combustion and for blowing into the openhearth bath through oxygen lances to accelerate the oxidation of carbon from the bath), 10% to the increase in hot metal iron charged to the furnaces from the blast furnaces, and a remaining 5% of this gain in production (and the decrease in fuel consumption) was attributed to the instrumentation.

The last statement was of considerable interest to the conference, inasmuch as it indicates that instrumentation has played an appreciable part in this production gain. It was emphasized that in any instrumentalized process, however, the operators must be sold by an alert and aggressive technical organization as to the proper

help they will get from the instruments. Par-excellent maintenance is a must, particularly necessary in order to gain the confidence of the operators in their instruments.

Of particular interest was Mr. Cauger's views of the gas dispatcher's panel board. It houses all the recording and integrating meters for the major fuel consumers. Some of these consumers were located as much as 15 miles from the dispatcher's office. By means of these recording telemetering meters, he can observe what quantities of fuel are being used at the various plant locations and also what gaseous fuel is being received from the coke works and other sources, and therefrom can allocate the use of all available fuel to the various consumers in the most efficient manner. From this reporter's experience, this gas dispatching control has assumed an extremely important function in assuring continuous and most efficient use of steel plant fuels.*

Roof and Bath Temperature

A lengthy discussion from the floor, after Messrs. Conway and Cauger had presented their papers, arose as to the merits of openhearth automatic roof temperature control. At the Wheeling Plant the roof temperature is recorded on a chart visible to the furnace operators. They, of course, know that the roof has the expectation of a relatively short life, in the neighborhood of four to six months. Roof refractories cannot successfully stand temperatures above 3050° F. Above this the roof brick melts or "sloughs off" (the term frequently used). Some commentators reported that the fuel input should be automatically reduced when the maximum safe temperature was reached. The location of the primary element (that is, the sighting tube focussed on the hot brickwork) was much in question. Some instrument engineers reported satisfactory results from an opening through the back-wall or the front-wall of the furnace through which a radiation pyrometer could be directly sighted on the inner surface of the roof. Others reported successful results when the sighting tube is located outside and on top of the roof, and the pyrometer focussed on a tube block integral with the roof brick.

One important factor in the production of uniform steel, heat after heat, is the temperature of the metal in the furnace during the refining stage. The history of the efforts to measure this temperature quickly, cheaply and accurately was outlined in the first part of "Comparison of Methods of Measuring Molten Metal Temperatures" by J. W. Percy of United States Steel Co. Today, Mr. Percy reported, there are two primary methods. One uses an open tube inserted beneath the molten slag. Clean, dry compressed air is applied to this tube of sufficient pressure to prevent any steel or slag from rising into it. A thermopile located within the tube then reads the millivoltage generated from the radiation coming into its open end, and this is recorded on a speedy electronic dial graduated to read directly in temperature. This method requires about 8 sec. immersion to obtain a proper reading.

The second method is by use of a special platinum thermocouple which, by nature of the protection designed into it, will withstand steelmaking temperatures. The millivoltage generated is, in the same manner, recorded on a fast-moving recorder. It requires about 25 sec. immersion to obtain a proper reading. From Mr. Percy's paper, one would gather that either of these two methods produces the desired result — that of measuring the temperature of the molten steel before tapping. The result of such temperature control is not only to produce steel of an improved quality but also to reduce or eliminate ladle "skulls" which are the results of a heat which is too cold. On the other hand, if a heat is tapped at too high a temperature the result is "stickers" — ingots which stick to the mold's stool.

It was a welcome surprise to hear reports that unreliable readings with this type of equipment were in the neighborhood of one in 100, which, when one considers how the ordinary furnace operator usually handles such equipment, indicates the fine progress which has been made by the instrument engineers and repairmen in designing and servicing rugged equipment.

Lester Veiock of the Heppenstall Co. presented a separate paper with many colored slides on "A Thermocouple System for Molten Metal Temperature Measurement". His company has obtained the greatest value from this instrument in the operation of acid openhearths. An average of 80 to 100 readings is being taken with

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*EDITOR'S NOTE — At a recent visit at the most modern Geneva (Utah) plant The Editor found that instrumentation at all points — blast furnaces, openhearth, soaking pits, rolling mills — was extra good. It undoubtedly contributes to the efficiency records the operators are setting. One most elaborate installation in the main powerhouse exercises remote control of all important power circuits (motors, even) so as to avoid surges after temporary shutdowns and undue peaks of demand. The latter is unusually necessary since the Geneva power plant is hooked into the intermountain network.

each couple, according to Mr. Veiock, before any repairs are necessary to the couple assembly, with the exception of course of the graphite plug and quartz tip which are always renewed before each reading. Some have lasted well over 200 readings. One precaution not usually regarded is that all couple wires must be handled with clean hands; oil or grease will contaminate the couple wire. In Heppenstall practice, two readings are usually secured per heat. These, taken within an hour of tapping time, enable the furnace operator to control his fuel input so as to obtain the desired bath temperature.

There are so many factors involved which are conducive to better general operation and lower costs of openhearth practice that only a few of them can be mentioned here. Quality control is by far the most important and the temperature of the openhearth bath affects quality control immensely. Fuel conservation, refractory conservation, furnace life, furnace availability, increased yields due to elimination or reduction of skulls as mentioned previously, reduction of delays in the stripping of the mold from the ingot, and faster time between teeming and charging into the soaking pits are also important factors in steelmaking which can be improved by the use of this type of temperature measurement.

The present reporter feels that the bath pyrometer has a very important future. While progress has already been very commendable, as indicated by the papers presented by Messrs. Percy and Veiock, the need is now for further simplification. By the intense interest indicated, the instrument engineer will certainly make earnest attempts to achieve this simplification.

D. R. Loughrey, chairman of the session, commented on the expansion program at Jones & Laughlin's Pittsburgh Works. This includes eleven 250-ton stationary openhearth furnaces. The instrumentation contemplated on these furnaces will be pneumatic and electric, primarily. A full complement will include roof temperature control, furnace pressure control, and automatic reversal based on time, temperature difference, or maximum temperature, with the use of chromel-alumel couples in the flue outlets to the stack. The furnaces will also be equipped with arrangements for blocking of the fuel input, of the oxygen or of damper control during reversal (if such operation is found advisable). The furnaces will be equipped with burners for fuel oil, tar, coke-oven gas, and oxygen for combustion (and also for carbon reduction). Fuel flow, steam and oxygen pressure and flow, and gas pressure will be controlled.

Viscosity control, similar to that described previously, will be supplemented by individual reheaters for the liquid fuel and these will be under temperature control. A pilot control in the main circulating line of both the residual tar and fuel oil will maintain constant viscosity, and the temperature which is required for any desired viscosity can be measured as frequently as is found necessary. Readjustments will then be made at the individual furnaces to correspond to that obtained from the pilot viscosity control.

Various interesting features of the control house were described by the present reporter. The panel board will house all the necessary recording and controlling instruments. In addition to these, large indicating dials will be centered on the panel so that the furnace operator will read therefrom all the pertinent information necessary in the operation of his furnace. The various levers, knobs, hand senders, and lights will be conveniently located on an outside console in front of the instrument house. There will be little need to enter the control house, since all control mechanisms will be within easy reach from the outside front. A safety feature will be that no gas or liquid fuel lines will enter the instrument house. The primary elements will transmit their respective values by pneumatic signal, and the panel board and console will be equipped with pneumatic piping and solenoid valves. Design of the various servomechanisms and the location of the instrumentation on the panel board and outside console were primarily dictated by what would be the best, operatively, from the melter's viewpoint. Ease of maintenance, while kept in mind, was considered a secondary factor.

Servomechanisms

A forum on electric, hydraulic, and pneumatic servomechanisms occupied one afternoon of this conference. Andrew J. Fischer, assistant chief engineer in charge of construction of Bethlehem Steel Corp., was the chairman, and Elwood T. Davis of Leeds & Northrup Co., H. Ziebolz of Askania Regulator Co., and A. A. Markson of Hagan Corp. formed the panel of experts.

The essence of the presentation indicated that the process to be served usually governs the type of servomechanism to be used. The response from the audience in the discussion indicates that — for various reasons, advantages and disadvantages — all three mediums, electric, pneumatic and hydraulic, are widely used and accepted as satisfactory.

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Materials for Fluorine Control Equipment*

Although chemists have been cognizant of certain remarkable characteristics of fluorine, only within recent years have a few of the practical potentialities of this element been realized. Since World War II, some of the industrial applications of fluorine have been discussed in *Industrial and Engineering Chemistry*, Vol. 39, March 1947. However, information pertinent to the handling of liquid and gaseous fluorine under high pressure has been extremely limited. It is hoped that these remarks will supplement the existing knowledge of suitable construction materials for liquid and gaseous fluorine technical environments.

Successful handling of fluorine is dependent on careful selection of construction materials and the observance of unusual precautions to assure that equipment is free from contamination. At pressures around 600 psi., liquid fluorine presents unique handling and control problems. A reaction between liquid fluorine and circuit contaminants or between liquid fluorine and improper construction materials ordinarily results in ignition of the containing metal contiguous to the reaction zone. Fortunately, nickel and several high-nickel alloys have demonstrated excellent resistance to the action of gaseous and liquid fluorine and have made possible the safe handling of this formidable element over a wide range of operating pressures and temperatures.

Tank — The low boiling point (−187° C. at a pressure of 1 atmosphere) and hazard potential of fluorine dictate close temperature control of the storage and feed systems. A small capacity, high-pressure storage tank for liquid fluorine is shown in Fig. 2. This tank is composed of three units: An inner container for liquid fluorine, a container for liquid nitrogen, and a high vacuum insulating shell. The covers for these three components were made integral with the central family of concentric fittings by welding. The liquid fluorine container was made of "A" nickel. This unit was machined from forged stock and arc welded with nickel (131) electrodes. Particular care was taken to remove welding flux and oxidation scale from the inner surface of the fluorine container, and all weld unions were given a rough polish. Annealed nickel of approximately Brinell 95 was used for the sealing ring in the cover of the fluorine tank.

This container was designed for a working pressure of 600 psi. The tank structure for the nitrogen and vacuum jackets was made entirely of Monel. All Monel welds were made with Monel (130 X) arc welding electrodes. The welded sections of this tank were not given a stress-relief heat treatment. When moisture was removed from the nickel tank prior to the introduction of fluorine, the nickel exhibited no noticeable corrosion. Appreciable nickel fluoride deposits, however, resulted when water was not removed. On the basis of subsequent experience, pure nickel is inferior to Monel as a liquid fluorine container because of its susceptibility to attack by hydrofluoric acid, which is extremely difficult to avoid in a fluorine system.

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Piping—Liquid nitrogen and vacuum jackets were extended to the liquid fluorine feed lines. The fluorine channel was made of "A" nickel seamless tubing. Monel has subsequently proved superior for this application, for the reason just mentioned. In order to reduce differential thermal expansion, the expansion ring and jacket

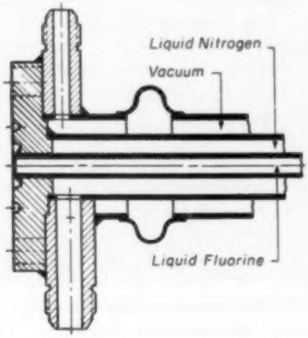


Fig. 1 — Section of Liquid Fluorine Feed Line. An expansion ring was used on each pipe length

tubes were made of Monel. The weld end fittings provided continuity for the nitrogen and vacuum jackets around the flanges. Flange sections were of "K" Monel; rings of soft nickel effected the interflange sealing.

The "K" Monel has shown the same excellent resistance to liquid fluorine as has Monel. Flanges were machined from cold rolled stock and were not age hardened for this application. Age hardening has not, however, proved to be detrimental to the fluorine resistance of "K" Monel and "Z" nickel.

All welding was done with Monel (130 X) electrodes. A satisfactory Heliarc rod for Monel was developed subsequent to the manufacture of this original equipment. The Heliarc technique (using argon gas) has proved superior to the arc method for Monel welding applications where small dimensional tolerances and good penetration and homogeneity were mandatory. When the surface of the weld has been cleaned and rough-polished, Monel arc and Heliarc weld sections have shown the same stability to liquid fluorine as has the parent metal.

Valve—A valve, with the functional characteristics desired of a quick-opening, high-pressure unit, presents some difficult conditions for construction materials. One valve design which has given satisfactory service as a high-pressure control valve for liquid fluorine is a gas-operated valve utilizing spring and gas pressure to provide shutoff in the event of failure of the solenoid which supplies the actuating gas. Two critical points are the seating surfaces and the valve-stem packing. Complete shutoff for working pressures up to 800 psi. has been achieved by seating 2S aluminum against Monel. An aluminum insert was shrink-fitted into the Monel pintle to provide the seating face.

The stability of 2S aluminum in fluorine is inferior to that of Monel, and small quantities of aluminum fluoride cannot be avoided. Despite multiple impacts in a liquid fluorine atmosphere under pressures of the order of 600 psi., the working life of the aluminum has been sufficient to justify its use in view of the excellent seating properties in conjunction with Monel. Soft nickel (Brinell 90) could probably be used as a seating face against age hardened "K" Monel or "Z" nickel. The differential hardness between Monel and nickel was not sufficient to yield a reliable gastight seal with this design.

A Sylphon bellows of Monel was used to separate the secondary packing gland from the

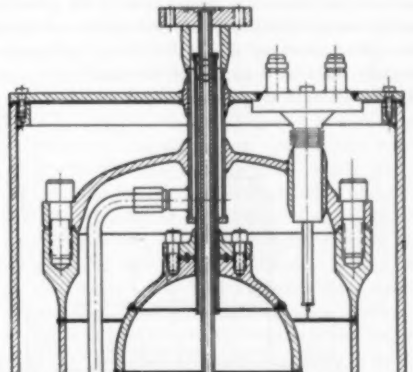


Fig. 2 — Schematic View of Fluorine Tank. Inner vessel was made of "A" nickel; outer ones of Monel

liquid fluorine. This single-ply bellows was silver soldered to the pintle and body. The soldered areas were heavily nickel-plated to provide corrosion resistance to the liquid fluorine. All traces of the organic masking compound used in the plating were removed, and the soldered, plated zones were carefully pressure tested prior to use.

Subsequent to this design, a compact composed of flake graphite, powdered nickel, and acid-treated shredded asbestos was developed and found to be satisfactory as a primary valve-stem packing for the liquid fluorine valve. This compact permitted elimination of the cumbersome bellows and a simplification of the valve design. Because of its antigalling characteristic, "S" Monel was used in the piston housing. This alloy has not been exposed to liquid fluorine. Its stability in high-pressure (500 to 600 psi.) gaseous fluorine appears equal to that of Monel. In most cases the presence of a thin fluoride deposit on Monel and "K" Monel could be attributed to circuit contaminants.

Flowmeter — Precise flowmetering of liquid fluorine has been a prime requisite. Flowmeter applications provide a severe test of the physical and chemical stability of a construction material for a given working fluid. Sustained calibration integrity usually depends on the maintenance of rather precise geometrical relationships between the various meter components. Corrosion of primary meter elements is a particularly unwelcome occurrence.

A rolling-ball type of flowmeter, which has satisfied the unique demands of liquid fluorine service, is shown in Figs. 2 and 3. In principle, a helical motion is imparted to the fluid stream by the multihole orifice plate. This motion effects rotation of the ball element around the track. The rotation rate of the ball is determined by the magnetic pickup working in conjunction with an electronic computer. A ball material of relatively high permeability is required. Surprisingly, a Type 440-C stainless steel ball gave excellent service. Over an aggregate running time of about 1 hr. in liquid fluorine at 900 to 1600 r.p.m., the weight loss for a 1-g. ball was less than 0.25%. Surface deterioration of the ball, though readily apparent, did not have an appreciable effect on the meter calibration. "Z" nickel, age hardened to about Brinell 330, was employed for the critical orifice plate, track, and retainer elements. The ball contact lines on the track were visible. Profiles of the running groove (taken at 32 ×), however, failed to reveal surface deformation after a total period of operation (in liquid fluorine, liquid oxygen, liquid nitrogen, and water) exceeding 36 hr. at 600 to 2000 r.p.m.

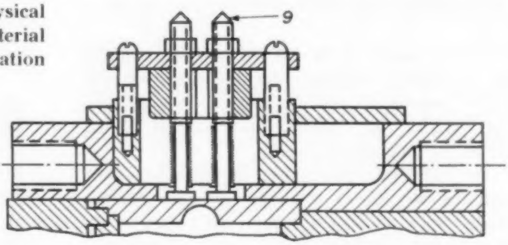
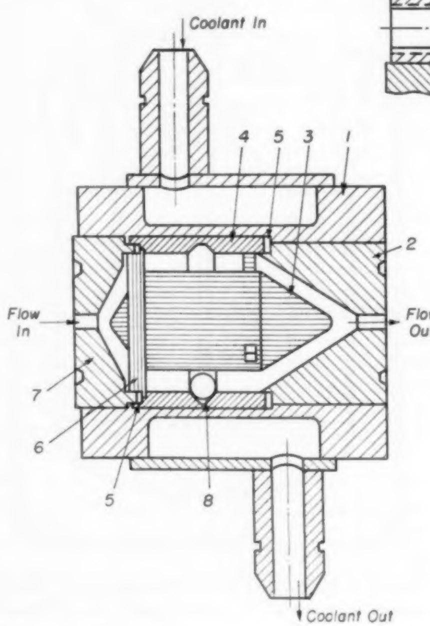


Fig. 3 — Liquid Fluorine Flowmeter Provided Accurate Metering Under Highly Corrosive Operating Conditions. Components indicated are: (1) Monel jacketed housing, (2) Monel outlet adapter, (3) "Z" nickel retainer, (4) "Z" nickel ball race, (5) 2S aluminum or copper gasket, (6) "Z" nickel orifice plate, (7) Monel inlet adapter, (8) 440-C stainless steel ball, (9) magnetic pickup assembly



The core element, subject to less mechanical working, was unaffected by this span of operation. It is testimony to the stability of "Z" nickel in this severe operating environment that, after approximately 1 hr. of running time in liquid fluorine under an average pressure of 500 psi., the combined deterioration of the orifice

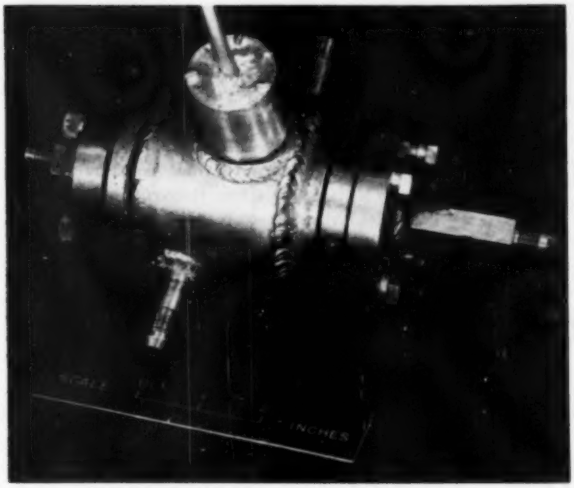


Fig. 4 — Flowmeter Is Compact Despite Jacketing

and track has not been apparent in precise recalibrations of this meter. The upstream and downstream adapter sections and the casing were made of Monel. Despite the incorporation of liquid nitrogen jacketing, the compactness which has been achieved in the construction of this meter is evident in Fig. 3.

Handling Gaseous Fluorine

The excellent stability of pure nickel and Monel in gaseous fluorine under conditions of low pressure and moderate temperatures (less than 700° C.) is well known. Copper, mild steel, 2S aluminum, and magnesium suffice for certain applications in gaseous fluorine. The corrosion of these latter materials is severe in a hydrous atmosphere, particularly when mechanical action is permitted to implement the descaling of their inherently unstable fluoride deposits. As a result, the use of these metals is quite limited. In most fluorine equipment, it is highly desirable to minimize the fluoride formation and provide the maximum safety margin for the extraordinary conditions which might develop. Nickel and Monel are far in advance of other materials in meeting these requirements.

At this laboratory, Monel and nickel have been employed exclusively in the gas-phase system between the electrolytic cell and the condenser. Fluorine was produced by the electrolysis of potassium acid fluoride in a 1500-amp. Harshaw cell. The hydrogen fluoride in the gaseous fluorine was removed by absorption in sodium fluoride pellet columns. The purified gas was then directed to a liquid nitrogen primary condenser before discharging into the storage tank. Monel finds application as tubing, filter screens, and thermocouple shields, nickel for the sodium fluoride purification towers.

A simple globe-type valve with a cast-nickel body, Monel pintle, and soft-nickel seating surface has been used for control. By constraining the pintle to a longitudinal motion, a considerable reduction in wear of the seating surface has been effected. The pressures encountered in this gas phase system have been low (less than 1 lb. gage pressure) with temperatures ranging from ambient to about 212° F. The gas velocity varied from zero to about 6 ft. per sec.

For these conditions, Teflon valve-stem packing performs satisfactorily. The packings are the only exception to the all-metal containing system for the gaseous and liquid fluorine. The fluorinated plastics such as Teflon have proved to have somewhat restricted limits of applicability in gaseous fluorine and have demonstrated a complete inadequacy for service in liquid fluorine. The nickel and Monel equipment of this gas phase system has exhibited practically no deterioration when proper cleaning and drying procedures were observed.

From qualitative examinations of equipment, nickel and Monel have performed equally well under similar operating conditions. The excellent resistance of Monel to hydrogen fluoride over a wide range of concentrations and temperatures, in addition to the superior mechanical properties achieved relative to nickel, recommends Monel as a general construction material for gaseous fluorine equipment. The gaseous fluorine environments presented by the installation at this laboratory have fortunately been confined to low pressures and moderate temperatures. Even under these conditions, however, the advisability of restricting construction materials to Monel has been demonstrated.

Although the scope of these observations is necessarily limited (the securing of quantitative corrosion data has not been an objective of the fluorine work at this laboratory), it is believed that this service experience has been sufficiently diverse and severe to permit a prediction that these materials will find considerable use in the expanding fluorine technology.

Bonding of Titanium Carbide With Metal*

By Walter J. Engel,
Cleveland

EFFORTS to increase the power of aircraft turbines have raised a number of problems concerning materials suitable for use at temperatures higher than those currently prevalent. Some that show considerable promise for high-temperature application in jet engines have been fabricated from combinations of ceramics and metals (the so-called "ceramals") by the sintering process. This process affords a means of producing compositions at temperatures below the melting point of the ceramic constituent. Controlled sintering of a powdered ceramal compact is generally capable of producing satisfactory homogeneity and grain size. However, an investigation of the mechanisms for alloying or bonding of metallic and ceramic materials is necessary for the maximum utilization of ceramals in aircraft power plants.

Consequently, an investigation was made at the N.A.C.A.'s Lewis Flight Propulsion Laboratory to study the bonding of titanium carbide with various elements, and to accumulate information regarding the mechanism of bonding. Although the conditions of this investigation were not directly analogous to those prevalent in the sintering of a body of intimately mixed powdered constituents, the reactions between the powdered elements and the solid titanium carbide were regarded as indicative of those between intimately mixed, discrete particles, as in a sintered powder body.

Titanium carbide was selected as the base material for bonding studies and theoretical evaluations because of its relatively high thermal shock resistance. (Messrs. Gangler, Robards and McNutt had already studied the physical properties of seven ceramics in N.A.C.A. Technical Note No. 1911.) Cupped, hot-pressed bodies of titanium carbide were obtained from the Norton Co. of Chippawa Falls, Canada. Metallographic examinations of sectioned specimens were made in order to determine the type of bond between the titanium carbide and the elements. In those instances where the metal pellet separated from the cupped surface of the carbide during the preparation of microspecimens, additional specimens were made and observed.

Materials — Cupped bodies were fabricated by the Norton Co. from carbide having a particle size of approximately 5 microns. A composite spectrographic chemical analysis of the bodies (based upon separate determinations by two laboratories) is:

Titanium carbide	96.50 ± 0.86
Boron	Trace
Carbon (excess)	1.90 ± 0.60
Columbium	0.10
Cobalt	0.05
Chromium	Trace
Iron	0.01
Nickel	0.08
Silicon	0.30 ± 0.20
Titania and/or titanium nitride	1.00
Tungsten	0.06 ± 0.06

wherein the values for titanium carbide and titania are calculated. The excess carbon, according to the manufacturer, appeared to facilitate compression of the powder. Apparent density measurements of the bodies averaged 4.78 g. per cu.cm., as compared with 4.91, the calculated theoretical density of titanium carbide.

Aluminum, beryllium, chromium, cobalt, columbium, gold, iron, lead, magnesium, manganese, nickel, platinum, silicon, titanium, and vanadium were selected for investigation as bonding agents. Elimination of other metallic

*This article reproduces, substantially complete, Technical Note No. 2187 of the National Advisory Committee for Aeronautics. The author is research metallurgist in the N.A.C.A.'s Lewis Flight Propulsion Laboratory.

elements was done on the basis of availability and temperature limitations of equipment. The ones chosen are described in Table I.

Apparatus and Procedure — A muffle type of furnace employing a helium atmosphere was used in fusing the powdered elements in the carbide cups. Heat was furnished by a graphite resistor. The muffle was a tube about 6 ft. long, 4 ft. 9 in. of which was inside the furnace setting, whereas 1 ft. 3 in. protruded as a cold zone for cooling the sample. The middle third of the furnace was a hot zone of substantially constant temperature. Impurities introduced in the helium atmosphere were of the type common to controlled atmospheres at atmospheric pressure for sintering furnaces.

Table I — Powdered Metals

Metal	Purity*	Particle Size (Tyler Mesh)	Supplier	Furnace Temperature
Aluminum	99%	−100	Charles Hardy	1300° F.
Beryllium	Premium grade	−325	Brush Beryllium	2550
Chromium	99.5	300	Charles Hardy	3000
Cobalt	97.5	300	Charles Hardy	2800
Columbium	99.8	−400	Charles Hardy	3650
Gold	99.9	−100	Charles Hardy	2050
Iron	98.5	300	Charles Hardy	2900
Lead	—	10	—	700
Magnesium	—	Ribbon	—	1300
Manganese	99	99.9%; −325	Metals Disintegrating	2400
Nickel	99.9	300	Charles Hardy	2750
Platinum	99.9	−100	Charles Hardy	3300
Silicon	97	−325	Charles Hardy	2680
Titanium	98.5	95%; −325	Metal Hydrides	3350
Vanadium	92	20	A. D. Mackay	3200

*As reported by suppliers, excluding occluded gases.

The carbide bodies consisted of small rectangular bricks, ⅝ in. square and ¼ in. thick. In the center of the top surface was a semispherical depression about ¼ in. in diameter and ⅛ in. deep. This cup was filled with the powdered metal to be tested, and heaped up approximately ¼ in. above the top surface. A graphite boat, shaped to the bottom contour of the furnace muffle, carried the loaded refractory cup. It was placed in the first warm zone of the furnace at about 500° F. After 5 min. in this preheat, the boat was pushed into the hot zone.

The temperature of the hot zone during each test is given in Table I and was generally about 100° F. above the melting point of the corresponding metal. While in the hot zone, the powder mound was observed through a glass-covered observation window. When it slumped, the loaded boat was immediately placed in the warm zone near the exit for 5 min., then moved forward into the cold end for 5 min. and finally removed from the muffle. The flow of helium through the furnace was increased from 50 to 250 cu.ft. per hr. preceding and during any operation involving opening the furnace door while a specimen was in the warm or hot zone.

A diamond circular saw used to cut the cup across its center left a good surface, facilitating polishing operations. The specimen was mounted on bakelite and then polished on silk laps with diamond abrasives. A hot aqueous solution of potassium hydroxide and ferricyanide was used as etchant. Scratch hardness with a Bierbaum microcharacter used a load of 9 g. because the standard load of 3 g. would not visibly scratch many of the surfaces investigated. Widths of the scratch impressions were measured with a calibrated eyepiece and a microscope, resolving at a magnification of 2000 diameters.

The X-ray diffraction patterns of the residue material at the original interface between titanium carbide and the melted metal in the nonadhering specimens were photographed by the Debye-Scherrer-Hull powder method, using different size cameras — that is, diameters of 57.3 and 143.2 mm. The sole known pattern observed was that of titanium carbide. However, some patterns contained several unidentified lines. Apparently, the titanium carbide was acquired as a contaminant while accumulating the residue.

Results of Observations

Nickel, cobalt, chromium, and silicon individually bonded with titanium carbide sufficiently well to withstand preparation of metallographic specimens. Silicon specimens were fragile — that is, they were more easily broken in the sectioning operation than the four others.

Metallographic conclusions were based on numerous observations as well as the micrographs reproduced herewith. A typical example of the internal structure of the original titanium carbide is shown at the bottom of Fig. 4. The black spots occupy about 25% of space in the total structure; some may be due to the excess carbon shown in the chemical analysis. How-

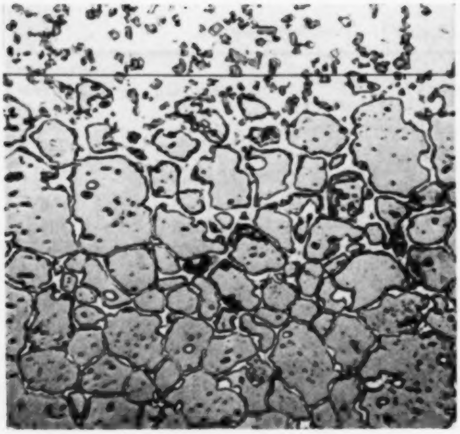


Fig. 1 — Micro of Alloying Action Near Original Interface (Ruled Line) Between Powdered Nickel and Titanium Carbide Body. 750×

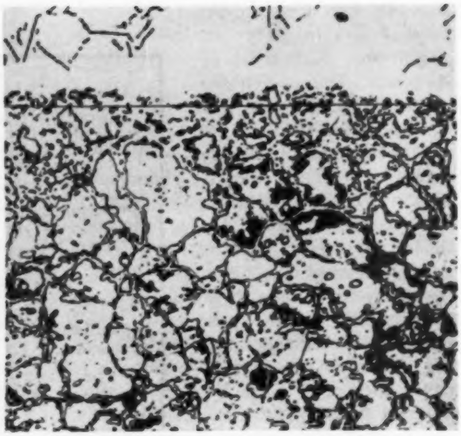


Fig. 2 — Cobalt-Rich Zone Above Interface With Titanium Carbide. All samples etched with solution of potassium hydroxide and ferricyanide

ever, the great majority are *not* voids. The titanium carbide matrix with nickel, cobalt, chromium, or silicon is shown in Fig. 1 to 4, respectively. Approximate location of the original titanium carbide surface is indicated by a horizontal line and is hereinafter termed the "original interface".

Nickel (Fig. 1) and cobalt (Fig. 2) formed distinct, interconnecting networks around the original titanium carbide grains. Nickel penetrated further below the original interface than cobalt, as determined by numerous microscopic observations. Although chromium (Fig. 3) clearly penetrated the carbide, it did not form a well-defined, interlocking microstructure. Silicon (Fig. 4) did not appear to penetrate between the carbide grains.

Nickel and cobalt remained as continuous phases down to the titanium carbide particles in the micrographs. Solution of titanium carbide was apparently followed by its precipitation, upon cooling, as separate particles in the nickel-rich as well as in the cobalt-rich zones; this is shown by the angular, relatively small particles. With chromium and silicon, new phases appeared to have formed adjacent to the titanium carbide.

Hardness — The average Bierbaum microhardness (9-g. load) of the specimens is presented in Table II.★ The zone rich in titanium carbide was always harder than the element-rich zone. At the original interface of nickel, cobalt, or chromium with titanium carbide, the hardness values were intermediate between the zones on either side. Average hardness at the original interface was highest for the cobalt specimen. Surveys of the actual element approaching the interface indicated that their hardnesses were relatively constant.

Evaluation of Observations

The criterion of a good bond between a metallic element and titanium carbide was the presence of a mechanical interlocking structure or the formation of a new phase. No consideration was given to the strength of the element. The value of an element as a binder was assumed proportional to the extent of penetration of the matrix by an interconnected phase.

Nickel and cobalt penetrated the titanium carbide along many of the grain boundaries. Silicon, however, did not penetrate between the grains to any appreciable extent. Penetration of chromium appeared to be intermediate. The type of penetration exhibited by nickel and cobalt is similar to one of the types described by Cyril Stanley Smith in his lecture on "Grains, Phases and Interfaces", published in *Metals Technology* for June 1940. He states, "If the interphase tension energy is less than one half that of the grain boundary . . . . . the second phase will penetrate along the boundary indefinitely." The temperatures we employed were sufficiently high for

★Editor's Note — The author writes: "The table regrettably has no hardness value for pure titanium carbide. The Bierbaum scratches were not sufficiently well defined to be considered as quantitative data even when the relatively high load of 9 g. was used."

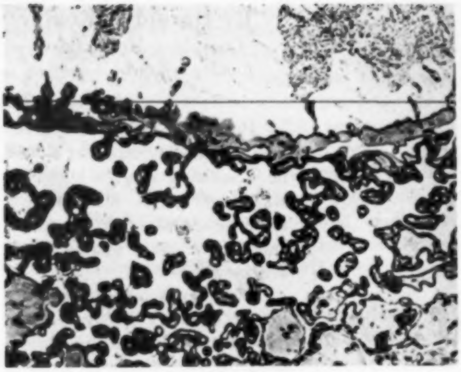


Fig. 3 — Chromium-Rich Zone and Extensive Interaction With Titanium Carbide Below Interface (Ruled Line)

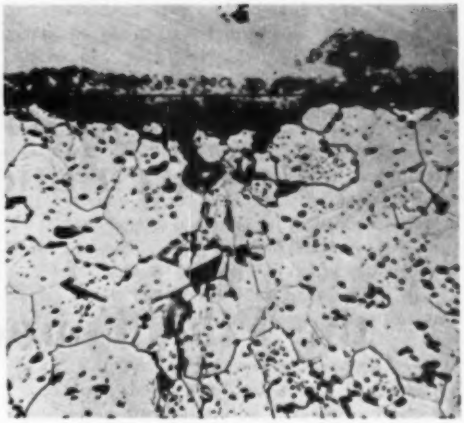


Fig. 4 — Silicon Penetrates Hardly at All

equilibrium angles to form between phases near the original interface.

Titanium carbide is soluble (perhaps to a limited extent) in the molten metal. This solubility is further evidenced by the presence of precipitates in the metal-rich zones. The fact that these precipitates are noncontinuous would probably endow a ceramal body of these materials with relatively good thermal shock resistance.

Both chromium and silicon adhered to titanium carbide after cooling below the melting point. The amount of penetration, however, suggests that neither element surrounds the titanium carbide particles as thoroughly as nickel and cobalt do. Also, the absorption of either carbon or titanium, or both, may have formed continuous insoluble phases in the element-rich zone, which, upon cooling, probably are not as ductile and thus not as resistant to thermal shock as a solid solution containing noncontinuous phases. This effect may have been responsible for the fragility of the bond between silicon and titanium carbide.

The hardness readings in Table II indicate that the hardness of each element-rich zone was fairly uniform. Larger quantities of titanium carbide were present in the nickel and the cobalt interfaces (compared with those of chromium and silicon), which may account for the higher hardness of these interfaces.

Since the element-rich zone is softer than the original interface, a marked difference should exist in either the composition or condition (or both) for specimens of titanium carbide with nickel, cobalt, or chromium. A large increase is not noted for the silicon specimen. Furthermore, the increment in hardness between the original interface and the titanium carbide zone for all the described bonded specimens shows that a change in material composition or condition, or both, has occurred.

Summary of Results

In summary, it may be stated that of the fifteen elements tested, only nickel, cobalt, chromium and silicon bonded with solid, high-density titanium carbide. Nickel and cobalt produced the most extensive bonds; chromium and silicon were less effective in penetrating and forming extensive interlocking networks. The appearance of small, angular-shaped precipitates in the nickel-rich and cobalt-rich zones somewhat substantiated the premise that there is some solubility (limited perhaps) of titanium carbide in nickel and cobalt at temperatures above their melting points.

Nickel, cobalt, and possibly chromium appear to have some promise as binder materials for sintered titanium carbide bodies.

Table II — Average Microcharacter Hardness, 9-G. Load

Specimen	Zone		
	Element Rich	Original Interface	Titanium Carbide Rich
Nickel and titanium carbide	620	10,900	13,800
Cobalt and titanium carbide	1,200	16,400	18,300
Chromium and titanium carbide	760	2,800	16,400
Silicon and titanium carbide	5,400	5,800	17,800

By Harold J. Roast
Consulting Metallurgist
London, Ontario, Canada

Research and the Pilot Foundry

In the bronze foundry business, no less than in any other, one cannot remain stationary. There must be the desire for improvement, no matter how high a standard may have been established. As a matter of fact, the defective castings -- occurring as they do in all foundries -- are a constant reminder of the need for finding the cause and a remedy for such rejections. Such matters require research.

In a small foundry this may mean the trying out of an idea along with the regular day's work, or after the regular day is ended. In the larger foundries, anything that interferes with the production line is anethema. Especially is this true in "production foundries", that is, foundries where the work is of a repetitive nature. Not only does this cut the tonnage, but the nerves of the workers, molders, foremen, and superintendent alike are irritated -- and this again acts like sand in a bearing, to the general detriment.

It is, however, in these production foundries that improvement and therefore research is most necessary.

The answer is a pilot foundry.

In its simplest sense this means an area apart from the regular foundry where an elementary foundry can be housed, together with the minimum of personnel. Nevertheless, such personnel and equipment must be of the highest caliber if the best results are to be obtained.

Such a pilot foundry might have a floor area of about 20 x 75 ft., or 1500 sq.ft. It should be well ventilated and well illuminated. One third of the area should be partitioned off for office and records. It is assumed that a chemical and physical laboratory already exists elsewhere and is available when required. The essential equipment would be a melting unit, a standard wall pyrometer, steel flasks, molding sand, core sand, a small core oven, and a molder's bench.

Further, a machine of sufficient capacity to break any ordinary 200-lb. casting should be included, as well as a small metal band-saw, and a simple hydraulic machine capable of 1000-psi. water pressure suited to test pressure cylinders 4 in. diameter and 6 in. long.

Also necessary is a small but efficient fume cupboard for deep etch tests -- that is, the boiling of bronze in a mixture of nitric and hydrochloric acids for 10 min. The hot plate will require either electricity or gas. This fume cupboard should be in the pilot foundry, not in the chemical laboratory. The office equipment should include a good typewriter with a wide carriage to facilitate the typing of large data sheets, a steel file cabinet, and a modern desk.

The most expensive piece of equipment in the pilot foundry, but at the same time the most essential, will be the melting unit. So many foundry problems involve gassy and dirty metal, that the pilot foundry must be able to melt metal as free as possible from gas and dirt. These requirements are best met by the high-frequency, lift coil melting unit. The capacity of the crucible should be 200 lb. of molten bronze, and the melting time about 25 min. or less. In these days of rapidly changing prices one can only say that the cost of such a melting unit, installed complete, used to be in the neighborhood of $20,000. Notwithstanding its high initial cost, it is the writer's opinion that it can be fully justified by its contribution to the solution of research problems.

The minimum personnel required is one qualified metallurgist thoroughly experienced in foundry procedure, a junior assistant, and an intelligent molder who is capable of making cores and melting and casting metal. Of course, the metallurgist of the pilot foundry might also be the plant metallurgist.

Economics -- The saving in dollars that can reasonably be expected, based on the magnitude

of the foundry's operation, must considerably exceed the total expenditure of the pilot foundry. This figure of "expected saving" or "cost reduction" must always be the controlling factor for the amount to be invested in the pilot foundry.

The capital investment might be something like \$25,000, which at 5% would give \$1250 as annual interest charge. If the cost is to be amortized in 10 years, the annual write-off is \$2500. The running cost, including rental of foundry space, power, sundries, wages, might be \$20,000. Total is \$23,750 — say \$25,000 in round numbers.

A foundry whose percentage of unsalable castings, figured against all castings originally made, is 5% higher than a reasonable norm, and whose production is, let us say, 15,000,000 lb. annually, would have as an objective the saving of 750,000 lb. of castings. Assuming that these rejections had cost 12¢ per lb. including their proportion of the total cost of doing business (the metal, less its melting loss, is recoverable), the possible savings would be on the order of \$90,000, to which should be added the loss of profit had they been salable, and possibly a further amount if many of the castings had been machined before rejection.

On the foregoing basis the pilot foundry would justify its existence if it reduced the amount of defective castings by only 1½%. At the same time it would have added to prestige, for the sales department is not likely to be slow in publicizing the pilot foundry as an asset, particularly in developing the new ideas of customers.

The pilot foundry should be responsible to the president or managing director of the company, not to the foundry superintendent, because new ideas may be sent in for consideration that may or may not become a part of production. Further, one of the main justifications for the pilot foundry is to release the production line from the operations of applied research.

Such a pilot foundry would primarily concern itself with the following problems:

1. Can better sand be secured for the production foundry?
2. Can the core mixes be improved?
3. Can the melting practice be improved?
4. Can the gating of difficult castings be improved?
5. Can more efficient grouping of patterns on a single plate be devised?
6. The setting up of a correct procedure for handling new patterns.

The following slogan might well be written in large letters, framed and hung in the office:

A DOLLAR SAVED IS A DOLLAR EARNED —BUT ONLY IF THE COST OF THE SAVING IS LESS THAN THE DOLLAR

The Birth of S.A.E. 4340

In answer to The Editor's request for information on the development of the S.A.E. 4340 steel, Harry W. McQuaid, consultant, of Cleveland, sent us the following story:

IN 1927 the General Motors Truck and Coach Division, Pontiac, Mich., was developing a special magnetic brake which would stop a coach more quickly and smoothly than anything then available. However, the retarding torque it applied to the rear axle driveshaft was so severe that the spline segments would break out at each axle. These measured about 2½ in. at the root of the ½-in. square by 4-in. long splines. The steel used was S.A.E. 3240 openhearth grade which was not held to any grain size specification.

After receiving from the bus manufacturer much caustic criticism of axle quality, H. W. Alden, then chief engineer of Timken-Detroit Axle Co., advised the writer, who was chief metallurgist, that he would call up in five minutes for a steel analysis and treatment to get us out of trouble. The writer, together with O. W. McMullan, now chief metallurgist at Bower Roller Bearing Co., made up a specification which was hoped would reduce the spline failure to a commercial limit.

The carbon limits were not changed, but the 0.90 to 1.10% chromium of the 3240 was reduced to 0.60 to 0.80% while the 0.30 to 0.60% manganese was increased to a range of 0.60 to 0.80%. The chromium was reduced because of what we considered to be its adverse effect in the upper range on the transverse impact value. This effect was quite marked in steels which, as was usual then, were not deoxidized with aluminum. The manganese was increased because we thought that in the lower ranges it

was the most important factor in depth of hardening (or "response to quenching").

There was such a marked difference between the response of the 0.30% manganese S.A.E. 3240 steel and a 0.60% manganese steel that they could hardly be considered as being of the same type. The lower manganese type was considered especially subject to banding with consequent poor transverse properties. This was another factor in bringing it up to the 0.60 to 0.80% range where its effect was definite on reducing banding. It was also felt that the higher manganese was beneficial in the melting to insure good bath action and cleaner steel.

Molybdenum was added to improve the response to quenching and to obtain a more uniform martensite with less free ferrite. It was our belief that the molybdenum tended to simplify the heat treating by permitting a longer time between the removal from the furnace and immersing in the quenching oil. This was an important factor in quenching in open tanks from oil-fired oven-type furnaces. The object was to prevent any free ferrite formation in the as-quenched martensite in the highly stressed surface zone of the shafts. We decided that if 0.15 to 0.25% molybdenum could be so beneficial in the S.A.E. 4130, then 0.30 to 0.40% molybdenum should be better.

At that time a specification for grain size was rare but in view of the need for the highest transverse impact values it was advisable to specify a fine grain type and electric furnace melting. The higher manganese, the lower sulphur which was characteristic of the Timken electric furnace bearing steel practice, and the better balance with the lower chromium range, would give to the 1.60 to 2.00% nickel steel a response to quenching which was expected to be high indeed. When combined in the fine-grained type this analysis should insure the highest possible transverse impact value at the finished hardness of 379 to 405 Brinell.

Mr. Alden called the Timken Roller Bearing Co., and steel for an ingot was made in their special test furnace of our modified S.A.E. 3240. This was entered on our laboratory records as 43240, meaning S.A.E. 3240 plus molybdenum. The first blooms rolled were badly flaked so another ingot was made which was pit annealed in the blooms, rolled into billets, and sent to Detroit. These billets were forged into axle shafts, annealed, machined and heat treated to 379 to 405 Brinell. Two were taken to the General Motors proving grounds for test and when the special brake was applied stood up without a sign of trouble, although all the rivets were stripped in the ring gear.

As soon as the test results were known, the S.A.E. 3240 specification was changed to the Timken 43240 number and in a year or two the S.A.E. 3240 dropped out of the picture in favor of its direct descendant known as S.A.E. 4340. An effort was made several years later to improve on the S.A.E. 4340 but with little or no success. Although the specification was made up in less than five minutes, S.A.E. 4340 gives strong indication that inspiration comes even to metallurgists if the pressure is high enough!

H. W. McQuaid

Nominating Committee

IN ACCORDANCE with the constitution of the American Society for Metals, President Walter E. Jominy has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), treasurer (for two years), and two trustees (for two years each). This committee was selected by President Jominy from the list of candidates submitted by the chapters. The personnel is:

Karl L. Fetters (Mahoning Valley Chapter), *Chairman;* Special Metallurgical Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.

George M. Enos (Purdue Chapter), Chemical and Metallurgical Engineering Bldg., Purdue University, Lafayette, Ind.

M. L. Frey (Milwaukee Chapter), Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

F. T. McGuire (Tri-City Chapter), Deere & Co., Materials Engineering Dept., Moline, Ill.

J. C. Neemes, Jr. (North West Chapter), International Nickel Co., Northwestern Bank Bldg., Minneapolis 2, Minn.

S. R. Prance (Dayton Chapter), Inland Mfg. Division, General Motors Corp., 2727 Inland Ave., Dayton 1, Ohio.

R. B. Schenck (Saginaw Valley Chapter), Chief Metallurgical Engineer, Buick Motor Division, Flint 2, Mich.

L. P. Tarasov (Worcester Chapter), Norton Co., Research and Development Dept., Worcester 6, Mass.

F. M. Walters (Los Alamos Chapter), P. O. Box 1663, Los Alamos, N. M.

THIS committee will meet during the third full week in the month of May. It will welcome suggestions for candidates in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but any individual member of a chapter may suggest to the nominating committee any candidates he would like to have in office. Endorsements may be sent in writing to either the chairman or any member of the committee.

By William G. Theisinger
Regional Manager of Sales
Lukens Steel Co.
Houston, Texas

Origin and Use of Clad Steel Plate*

IN THE DECADE of World War I, the petroleum, paper, and chemical industries became acutely conscious of the need for better materials of plant construction to prevent its corrosion and the corresponding contamination of product. Metals and alloys were sought that possessed the desirable combination of corrosion resistance, high strength, ductility, relative ease of fabrication and reasonable cost. Obviously this was a large order, since no known material offered universal resistance to chemical attack. Likewise, if any one showed particular promise in a general way, it lacked one or more of the other essentials — physical properties, formability or price.

While steelmakers could accomplish excellent physical and mechanical properties, at a fair price, by a combination of the basic elements added to carbon and low-alloy steels, such metals still remained vulnerable to corrosive attack — even by the atmosphere. As we now know, considerable quantities of costly alloying elements are needed to produce a corrosion resistant steel. Even after the invention of the so-called stainless steels, there seemed to be no commercial method of solving the cost angle. Meanwhile, the manufacturers of certain industrial chemicals, notably caustic soda, dangled attractive prospective purchases of such a material in front of the steel mills' sales and development men.

Caustic soda in low concentrations can be transported in tank cars made of carbon steel with no serious deterioration of the tank; but unfortunately to do so the shipper must pay a high freight rate on a lot of water. In addition, the caustic dissolves enough iron during transportation to discolor the liquid. This results in further processing at its destination or else the chemical must be sold as a second-grade material, limited in application. The answer to this specific corrosion problem was found to be tankage of commercially pure nickel, but the dollar per ton-mile ratio of solid nickel tanks was too high for economical transportation.

It became evident, from further study, that any corrosion resistant metal or alloy, solid, would be too costly for tonnage applications. Researchers then turned their efforts toward a method of combining several metals physically. Nickel plating of a carbon steel tank was not long considered, due to the acknowledged porosity of such a coating. The use of an intermediate layer, like copper, between a nickel plate and steel backing might be more harmful than iron in the solution, should it be attacked by the caustic, if this chemical were to be used in the manufacture of rayon. Plating serves well in many fields; but, in the processing industries, a heavy, impervious coating is indispensable.

The evidence strongly suggested a rolled nickel sheet joined securely to carbon steel as the best possible solution. To develop this conclusion into a commercial product, in 1926 Lukens Steel Co. and The International Nickel Co. combined their research staffs and facilities.

The history of metals reveals the use of bimetallics since ancient times. Those composite metals had, for the most part, been employed for decorative articles in the home, although agricultural implements like plowshares and weapons had been made from them, wherein the brittleness of a hard surface was supported in its resistance to shock by a ductile material.

Bimetallics, of more modern usage, were usually joined by forging the heated metals together, which proved to be satisfactory for small parts. However, the making of shell plates and heads for a tank 8 ft. in diameter and 30 ft. long presented an entirely different set of conditions. Laboratory samples or the product of a forging hammer, no matter how large, would

*From Sauveur Memorial Lecture, given before the Boston Chapter ⊕, April 6, 1951.

not suffice for a railroad tank car. This proposition assumed even greater magnitude when material was suggested for huge oil reactor vessels, 26 ft. in diameter and 77 ft. high, made with $1\frac{1}{8}$-in. shell plate.

It is interesting to note that the tank car and the oil reactor exemplified generally the two major corrosion resistant requirements for pressure vessels. The tank car had to be built of a material that would not dissolve into the liquid — in this case causing little damage to the vessel itself, but having a serious effect on the contents. The oil reactor vessel must be fully protected from the severe attack induced by the high sulphur oil being processed. These two corrosive conditions appeared jointly to varying extents in many other industries, such as the making of soap, glycerin and chemicals, and the fermentation of beer.

The first bimetallics in actual plate form (soon to be called "clad steels") were produced in 1928, and commercial plates and heads were in service by 1930. Nickel was the first corrosion resistant metal to be bonded to carbon steel at the Lukens plant, followed soon by Monel and Inconel. Practically all the varieties of stainless steels are now used to make these composite plates, as well as silver, copper and aluminum. Other combinations, such as tantalum clad and Hastelloy clad, are under active research at the present time.

William G. Theisinger

As regional manager of sales for Lukens Steel Co., Coatesville, Pa., W. G. Theisinger has supervised Lukens district sales activities for 12 southern states since 1950. Prior to his appointment he was manager of technical sales. He joined Lukens in 1935 as a welding and metallurgical engineer, becoming director of welding research in 1941. He graduated from Harvard University from which he received the degree of Doctor of Science. Dr. Theisinger has also helped the N. Y. City Board of Transportation develop welding inspection, and Western Pipe & Steel Co., San Francisco, as consulting engineer on automatic welding.

Manufacturing Practice

Manufacturing procedure is essentially the same for all the clad metals, with obvious changes or precautions dependent upon the basic characteristics of the various alloy materials. While many different methods of covering one metal with another have been used in the last 20 years, the so-called "sandwich" process produces a material well suited to the requirements of production, fabrication and service.

The basic metal is an ingot of carbon steel, selected from an appropriate A.S.T.M. specification, that is rolled to slab form in a conventional rolling mill. This rolled slab (for example, 9 in. thick, 8 ft. long and 5 ft. wide) becomes the backing material of the sandwich or assembly. Its top surface is descaled and scrubbed to remove any foreign impurities. Two such slabs are so prepared and placed alongside each other.

Using the production of stainless-clad steel as an illustration, a 1-in. slab of stainless of the desired A.I.S.I. type is placed on each of the cleaned carbon steel surfaces. (Its under side had been previously plated with a moderately thick layer of nickel.) Then a paste-and-powder mixture known as a parting compound is spread over the top surfaces of the stainless slab.

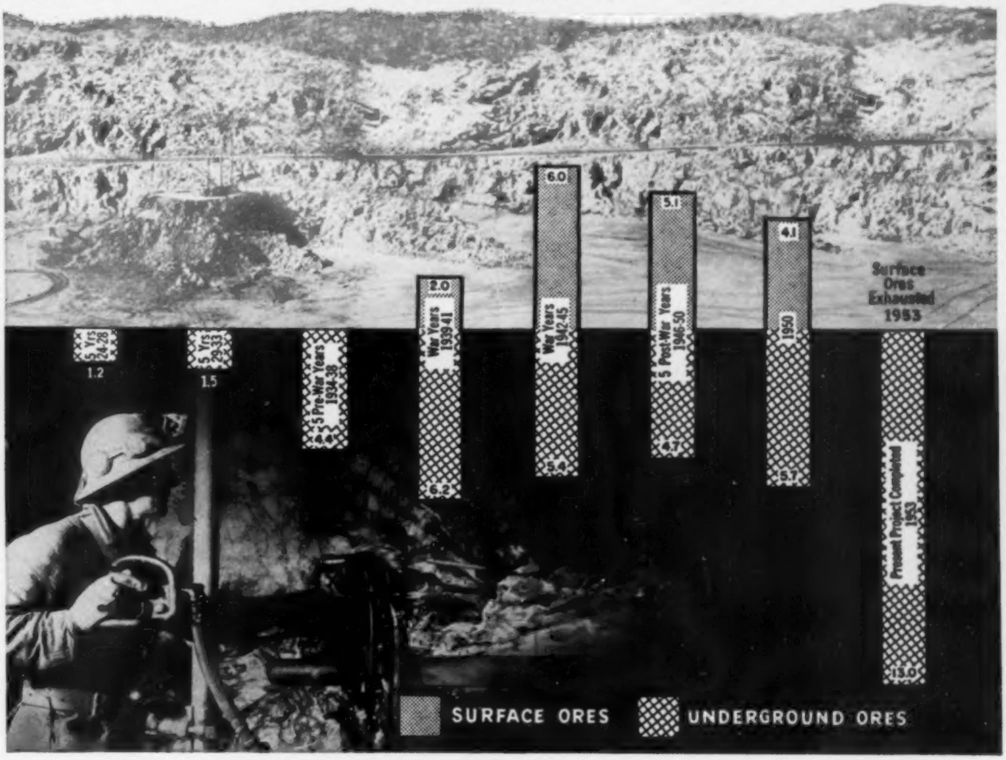
These two units are now placed one on top the other, so that the full assembly or sandwich is made up of a 9-in. carbon steel slab on the bottom, a stainless plate 1 in. thick, the parting compound, another piece of stainless, and on top of all is a 9-in. slab of carbon steel. Steel bars are placed around this pack, adjacent to the edges of the stainless slabs, and the whole assembly is welded together. Its total thickness is approximately 20 in.

The sandwich, now resembling the shape of an ordinary ingot of steel, is heated in a soaking pit to 2300 to 2400° F., and soaked for many hours to assure uniform temperature throughout. The white-hot slab is rolled in the 206-in. mill at Lukens, which furnishes the pressure needed to bond the stainless cladding to the carbon steel. As a finished plate 430 in. long, 150 in. wide and 1 in. thick can be produced from this pack on this mill, obviously the sandwich is cross-rolled.

After cooling, the edges of the pack are cut off with an oxy-acetylene flame, inside the welds that had been made previously to hold the pack together. The two clad steel plates can now be separated and each trimmed to size. If required, they may be heat treated in accordance with need. They are then descaled in sodium hydride.

All this seems reasonable and straightforward, as it should be for a *(Continued on p. 708)*

Underground and surface **ORE MINED** (yearly average—millions of tons)



Underground for Defense

...started more than 10 years ago

STRENGTH...military and economic ... depends on productivity. And productivity depends on men who have devoted long years to their specialized chosen field of endeavour.

Such men with "know-how" mine nickel from the rocky rim of Ontario's Sudbury Basin...

By increasing output with maximum speed and drawing on reserve stocks of nickel previously accumulated, they helped raise deliveries of nickel in all forms during 1950 to 256,000,000 pounds... a record for any peace-time year.

This record, 22% greater than the 209,292,257 pounds delivered in 1949, was no accident...

In 1937, INCO launched a vast long-range project which now makes it possible to meet the military requirements of the United States, Canada and the United Kingdom. In addition, nickel deliveries are being made to government stockpiles and the balance of the supply is being rationed among civilian consumers in all markets throughout the free world.

Since the inception of International Nickel, its fixed policy has always been to increase the supply of nickel. To meet today's needs, INCO went underground years ago.

Anticipating the eventual depletion of Frood-Stobie open pit surface ores, more than 10 years ago, INCO embarked on a program of replacing open pit with underground capacity. This required extensive enlargement of underground plants, development of new methods of mining not previously undertaken and the revamping of metallurgical processes to cope with difficulties in recovering nickel from the new types and lower grades of ores which have to be reached.

Major expansion in output of nickel from underground operations is being driven to conclusion with utmost speed. There is still much construction to be done and a number of mining and metallurgical problems remain to be solved and tested in actual operation. Barring unforeseen interruptions, full conversion to underground mining should be completed in 1953.

When the present undertaking is completed, INCO will be able to hoist 13,000,000 tons annually, and the size of its underground mining operation will surpass that of any other non-ferrous base metal mining operation in the world.

This underground expansion is being completed by INCO without interrupting current production of nickel, which is at maximum capacity.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Aluminum-Rich Binary Alloys

NOTE: Under "Size Factor" U means unfavorable for formation of solid solutions, where differences in atomic radii are greater than 15%.

Compiled by F. R. Morral

Group and Alloying Valance	Elements	Crystal Structure	Size Factor	Solid Solubility at 20° C	Solid Solubility Maximum	Solid Solubility Lattice Constant at %	Eutectic Melting Point °C	Eutectic % Alloying Element	Second Phase % Aluminum	Second Phase Melting Point	Second Phase Formula	Second Phase Crystal Structure	Lattice Constants KX Units a	b	c	Atoms in Unit Cells	References
IA 1	Li	⊞	+9.4	0.7	5.2	4.0382 at 1.93	600	9.9	79.5	719	Al Li	⊞	6.36			16	1,2,6,8
	Na	⊞	U														1,2
	K	⊞	U														2
	Rb	⊞	U														2
	Cs	⊞	U														2
IB 1	Cu	⊡	-10.8	0.1	5.65	4.0335 at 3.71	548	33	45.9	591	Al_2Cu	△	6.052		4.878	12	1,2,3,4,6
						4.0290 at 5.5											
	Ag	⊡	+0.7	0.5	48	4.0413 at 20.0	558	72	11.1	728	$Al\,Ag_2$	⬡	2.87		4.61		1,2,3,6,8
	Au	⊡	+0.7		0.2		650	8	21.5	1050	Al_2Au	□	5.9868			12	2
IIA 2	Be	⬢	U		0.05		645	0.87			Be		2.281		3.577		1,2,8
	Mg	⬢	+11.8	1.1	14.9	4.0861 at 9.6	451	33.0	62.5	+451	Mg_2Al_3	⊡	28.13			1172	1,2,3,4,6
						4.122 at 16.					Al_2Mg	⬡	11.38		17.87		7
	Ca	⊡	U	0.3	0.7		616	7.6	67.	p,700	Al_4Ca	◭	4.35		11.07		1,2
	Sr	⊡	U		<0.3		600	1.0	55.2		Al_4Sr	◭	4.45		11.05		2
	Ba	⊞	U				651	2.0	44.0	1050	Al_4Ba	△	4.53		11.14		2
IIB 2	Zn	⬢	-3.8	2.	82.8	4.0360 at 4.88	382	95.			Zn		2.6589		4.9349		1,2,3,6
	Cd	⬢	+6.2	0.15	0.97	4.0410 at 0.25	m,649	7.5			Cd		2.9727		5.6061		1,2,3
	Hg	▱	+8.3	5.6			-38.9	99*			Hg		2.999		α = 70° 32'		2
IIIA 0	B	▯			<0.05		658		55.5	p,1350	$Al\,B_2$	⬡	3.00		3.24	3	1,2
	Y	⬢	-8.1														2
	La	⬢	U				639	3.0	43.7	816	Al_4La	◭	4.42		10.20	80	2,7
IIIB 3	Ga	▯	-15.0				26.3	98	43.6		Ga		4.5167;	4.5107;	7.6448		2
	In	◬	+9.7		.05		156	98		634	13% in Monotectic		4.585		4.941		1,7
	Tl	⬢	U								2 Layers						2
IVA 0	Ti	⬢	+2.5	0.03	1.5%		p,665	1.*	62.8	1355	Al_3Ti	△	5.424		8.574	16	1,2
	Zr	⬢	+11.5		0.28		p,660.5	0.28	47.0		Al_3Zr	△	4.00		17.3	6	1,2
	Th	⊡	U				636	25.6	26.0	p,880	Al_3Th	⬡	6.480		4.601	8	2
IVB 4	C	◇	U						87.1		Al_4C_3	⬡	3.27		21.6		
	Si	◇	-7.3	0.01	1.65	4.0396 at 0.97	577	11.6		1430	Si		5.4173				1,2,4,6
	Ge	◇	-2.4	0.3	5.0	4.0446 at 5.06	424	54			Ge		5.647				2,3,6
	Sn	◇	+10.4		0.001		229	99.5			Sn		6.46				1,2
	Pb	⊡	U		<0.2		327.4	99.98		658.5	1.52% Pb Monotectic				4.9389		1,2
VA	V	⊞	-1.0	0.37	0.37	4.0403 at 0.18 and 630°C	m,660	0.10	78.8	p,750	Al_7V						2,7
	Cb	⊞	+3.7						46.5		Al_3Cb	△	5.427		8.584		2
	Ta	⊞	+3.7						30.9		Al_3Ta	△	5.422		8.536		2
VB 5	N	□	U						65.8		Al N	⬡	3.11		49.8		
	P	□	U								Al P	⊡	5.43				
	As	▱	-1.0						26.5	1200*	Al As	⊡	5.63			4	2
	Sb	▱	+13.0		<0.1		657	1.1	18.4	1050	Al Sb	⊡	6.13				1,2
	Bi	▱	U		<0.2		m,657	3.36			Bi		4.736		α = 57° 14'		1,2
VIA 0	Cr	⊞	-11.0	0.01	0.77	4.0377 at .5	m,661	0.41	78.4	p,710*	Al_7Cr	▯	19.99;	34.51;	12.47		1,2,7
						4.0345 at .85 (>600°C)											
	Mo	⊞	-2.2		0.2		660		58.5	p,735	Al_3Mo						2
	W	⊞	-1.3	1.7	1.7		p,660	<0.5	63.0	p,697	$Al_{12}W$						2
	U	▯	-3.5	Small			640	13		p,730	Al_3U						2,5,9
VIB	O																
	S	▯	U						18.5	960	Al_2S_3						
	Se	⬡	+1.3				659				Al_2Se_3						2
	Te	⬡	+12.6				621	3.0	51.4	895	Al_2Te_3						2
VIIA 0	Mn	□	-10.0	0.05	1.82		m,658.5	1.95	74.6	p,710	Al_6Mn	▯	6.485;	7.525;	8.840		1,2,4
VIII 0	Fe	⊞	-12.8		0.03		655	1.7	59.2	1160	Al_3Fe	▯	48.04;	15.59;	8.10	96	1,2,4
	Co	⬢	-13.2		<0.02		657	1.0	67.0	p,943	Al_5Co						1,2
	Ni	⊡	-13.9		0.05		640	5.7	58.0	p,854	Al_3Ni	▯	6.5982;	7.3518;	4.8021	16	1,2
	Pt	⊡	-3.2				630	9	45.4	p,760	Al_6Pt						2
Rare Earth Group	Ce	⊡	U		0.05		637	13.0	43.5	p,1005	Al_4Ce	◭	4.365		10.096		2,7
	Pr	⬢	U				658	14	43.4	1018	Al_4Pr						2
	Nd	⬢	U						15.6		Al Nd	⊡	3.73				2

□ is Cubic
⊞ is Body-centered Cubic
⊡ is Face-centered Cubic
⬡ is Hexagonal
⬢ is Close-packed Hexagonal
△ is Tetragonal
◬ is Face-centered Tetragonal
◭ is Body-centered Tetragonal
▱ is Simple Rhombohedral
▯ is Orthorhombic
◇ is Cubic Diamond
⫽ is Monoclinic

Notes: m = monotectic, p = peritectic

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Variables Encountered in Tracer Experiments in Metallurgy

RADIOACTIVITY is of interest to metallurgists principally as a tool to be used in solving some of its problems. This tool, tracer analysis, has been applied in the field of physical metallurgy in several different ways,[1] notably to determine diffusion coefficients in various systems,[2] and to measure the rate of oxidation of copper.[3] (References will be found on p. 680.) In the pyrometallurgical field it has been used to determine the amount of various forms of sulphur (whether organic, pyritic or free) removed during the production of coke.[4] In the mineral dressing field, it has helped to determine surface area of solid particles, and at present the reversibility of certain reactions as well as the affinity of mineral surfaces for special collectors are being investigated.[5]

These are typical problems which can be solved by tracer analysis. However, since each application of this unique method of analysis requires modifications to fit the experimental conditions, a general understanding of the field of nuclear physics and chemistry is necessary. A brief review will therefore be presented.

Radioactivity arises from the emission of an alpha or beta particle, a gamma ray,† or a combination of either particle with a gamma ray. Radioactivity results from the disintegration of the nucleus of an atom. Since over 95% of the artificial isotopes are either beta emitters or gamma emitters (or both), these are the types that are now most commonly employed for tracers. The various methods by which atoms can disintegrate are inconsequential; the important fact is that disintegration occurs and any inherent atomic instability has no effect on the physical and chemical properties of that atom before it disintegrates.[6]

In order to determine the magnitude of the variables encountered in a tracer analysis, we conducted a series of diffusion experiments by plating radioactive cobalt on cylindrical steel samples.

The isotope used in the present investigation was Co^{60} which was prepared by deutron bombardment of Co^{59} in the 60-in. cyclotron at the University of California. The radioactive element was converted to cobalt sulphate and diluted so that its activity was 750 microcurie units. (A microcurie is the amount of material which disintegrates at the rate of 37,100 per sec.)

A suitable electrolytic solution was prepared of 60 g. nonradioactive cobalt sulphate, 7.5 g. ammonium chloride, 7.5 g. boric acid and 500 ml. distilled water, to which was added six drops (19 drops = 1 ml.) of the radioactive cobalt solution, as received. The cell was operated under the following conditions:

pH of solution	5.3
Current density	0.07 to 0.11 amp. per sq.in.
Temperature	30 to 40° C.
Anode	Cobalt sheets

Cylindrical steel samples, used as the cathode, were then electroplated and heated for various times at 1830° F. (1000° C.). Thin concentric

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†An alpha particle is a helium atom stripped of its external electrons. Beta particles are high-velocity electrons and positrons emitted from the nuclei of atoms. Gamma rays are photons (quanta of radiation) of high energy.

layers were then removed from the steel cylinder and the turnings used to investigate the variables listed below.

Variables Affecting Experimental Procedure — The number of variables to consider depends upon whether an absolute or relative value is desired. Fortunately, many of the metallurgical applications can be determined by using relative values and under these conditions the following variables determine the experimental procedure:

1. Apparatus and its calibration
2. Background
3. Statistical fluctuation
4. Half-life of isotope
5. Condition of sample
6. Sample form:
   a. Solid angle or geometry
   b. Absorption
7. Coincidence counting

Apparatus and Calibration — The apparatus we used is shown in Fig. 1. It consists of an aluminum-lined lead housing containing the Geiger tube and a series of aluminum shelves to support the samples. The tube D is coupled to an electronic scale-of-64 circuit to resolve and record the activity of each sample. To increase the number of counts which can be recorded, a magnetic counter was connected to the output circuit of the last neon tube and consequently it registers in multiples of 64 counts. A timer, accurate to 0.01 sec., completed the group.

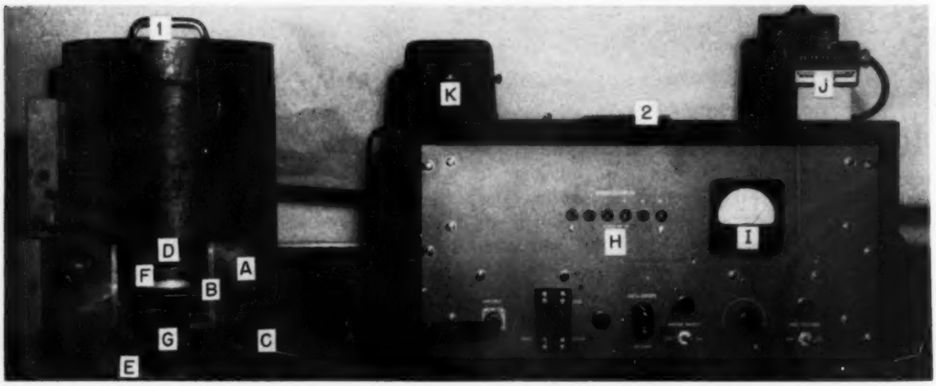

Fig. 1 — Geiger Counter With Housing (at Left) and Scaling Equipment

1 — Housing
A. Lead shield
B. Aluminum casting
C. Geiger tube
D. Geiger tube in place
E. Shelf
F. Shelf in place
G. Sample

2 — Scaling Circuit
H. Neon tubes
I. Voltage regulator
J. Magnetic counter
K. Automatic timer

The tube is a standard, end-window Geiger-Müller type consisting of a conducting cylinder along whose axis extends a fine tungsten wire (0.2 mil diameter).[7] It is filled with a mixture of argon and ethyl alcohol gas under a pressure of about 100 mm. of mercury. The front end is sealed by a thin mica window which can admit beta and gamma particles.

This apparatus is calibrated by placing a standard sample of a long-life isotope with strong emission (such as a compound containing uranium) under the tube and recording the number of counts per minute when different voltages are applied to the tube. Resultant plots would look like Fig. 2, in which curve No. 1 is just after the tube was put into service, while No. 2 is after the tube has been extensively used. The flat horizontal part is termed the "plateau"; since counts per minute do not vary with voltage on the plateau, it is the most suitable range for operation. As the tube becomes older, the plateau shifts downward and to the right as indicated by a comparison of curves No. 1 and 2 in Fig. 2. We operated the counter 50 to 75 volts beyond the knee (point A) of the curve — that is, at approximately 1390 volts, to minimize errors introduced by shifting plateaus. The gradual shift of the curve downward from C to D introduces no error, since a "background reading" taken before each series of tests automatically corrects for the lowering of the plateau.

Background — Cosmic rays (extremely high-energy rays originating in interstellar space which continually bombard the earth) register a certain number of counts each minute even in the absence of a radioactive sample. This is termed "background". A systematic study of

the variation of background from eight in the morning until five in the afternoon was made on two different days, and the results checked reasonably well. In general, the background counts per minute are 17.5 to 18.5 at 8 a.m., approach a maximum of 20 ± 0.5 at noon and decrease gradually to about 18.5 at 5 p.m. However, variations from hour to hour prevent one from accurately allowing for the background by determining it before and after each sample is tested. Attempts to use two circuits at the same time to determine the actual background during a test are invalid because of the different operating plateaus and the inherent nature of the housing. Therefore the best method of decreasing the error due to the variation in background is to increase the radioactivity of the sample to such a level that the variation becomes negligible compared to the total from the sample.

Statistical Fluctuations — Any analysis, even under the most favorable conditions, shows fluctuations due to the random and independent nature of the disintegration of atoms. Their final count can be correlated only by statistical analysis,[8] whose use will now be indicated in a very elementary way.

If N is the total number of particles counted in a given time and D is the deviation from the true value, then $D = \sqrt{N}$, and by definition the probable error $P.E. = 0.67\sqrt{N}$.

In an analysis, a background is determined and then the sample is placed under the tube and a measurement made. The deviation is now

$$D = \sqrt{\delta^2 + \varepsilon^2} = \sqrt{N_1 + N_2}$$

where δ = deviation of the count of background plus radiation

ε = deviation of the background count

N_1 = number of counts from background plus radiation

N_2 = number of counts from background

and the probable error is

$$P.E. = 0.67\sqrt{N_1 + N_2}$$

Fig. 2 — Variation in Counts With the Potential Applied, and Lowering of Plateau With Age (Use)

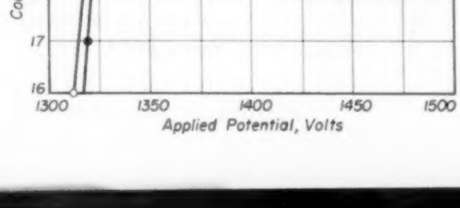

Table I — Determination of the Deviation, Relative Deviation and Relative Probable Error of an Analysis

Background = 19 counts; time of count = 60 min.

Sample	Total Counts $N_1 + N_2$	Size Sample	Counts per Unit*	D	R.D.	R.P.E.
1	63,710	11.6 mg.	89.9	252	0.40	0.27
1	56,036	10.2	89.7	237	0.42	0.28
1	60,814	11.1	89.6	246	0.40	0.27
2	31,680	10.9	46.7	178	0.56	0.38
2	29,100	10.0	46.6	171	0.58	0.39
2	28,482	9.8	46.5	169	0.59	0.40
3	15,665	8.9	27.2	125	0.80	0.52
3	17,134	9.8	27.2	131	0.77	0.51
3	17,502	10.1	27.0	132	0.75	0.50
4	2,164	11.3	1.51	46.5	2.15	1.45
4	2,077	10.4	1.50	45.5	2.20	1.47
4	1,992	9.6	1.48	44.7	2.24	1.50

*Counts per min. per mg. of sample.

Expressed as per cent of deviation of the true value, these magnitudes are termed the "relative deviation" (R.D.) and "relative probable error" (R.P.E.) respectively. Formulas are

$$R.D. = \frac{D}{N_1 - N_2} \text{ and } R.P.E. = 0.67\ R.D.$$

Table I indicates how these formulas are used to compute values for four experiments.

Although the values of counts per unit agree within ± 0.15 for all four samples, regardless of intensity of radiation (total counts), the relative deviation and relative probable error actually increase with a decrease in intensity. Consequently, high activities lend for accuracy. As a rough guide, a minimum of 40,000 counts per sample is desirable for an analysis. Although this value still yields a relative probable error of 0.33%, attempts to obtain higher counts (such as 360,000, which decreases the probable error to 0.1%) either require a long time or involve complications arising from the use of increased activity. For example, at high activities (of the order of 8000 counts per min.) a correction of almost 10% is necessary for "coincidence counting" — that is, the certainty that two atoms may disintegrate at such short intervals of time that the counter can register only one.

Half-Life — The half-life of an isotope is defined as that period of time in which the activity of the original sample is reduced to one half its initial value. This is represented by

$$N = N_o e^{-\lambda t}$$

where N = total number of active particles at time t

N_o = original number of active particles

λ = proportion of the remaining particles disintegrating per sec. (a constant)

e = base of natural logarithms

Lacking any precise information about the essential reason why, for example, Cr^{51} has a half-life of 26.5 days and Co^{60} a half-life of 5.3

years, and not being able to do anything to increase or slow these inherent rates, the best we can do is to select that radioactive isotope from those available which fits the conditions of the desired experiment and has as long a half-life as possible. The experimenter can then neglect corrections for loss of radioactivity during a test run. He can also keep a supply of the isotope in stock indefinitely.

In any event a special sample of the original material should be set aside and its radioactivity analyzed periodically to determine if the reported half-life is correct as well as to check for radioactive impurities and for isomers. (Some radioactive isotopes seem to have a dual personality; one portion has a different half-life from the remainder, yet both portions decay into the same element. These two portions are called isomers.) If the isotope being used is neither contaminated nor an isomeric type, a plot of log N versus t (time) will yield a straight line.

The isotope used in our investigation was an isomeric type with half-lives of 10.7 min. and 5.3 years. However, the one with the shorter half-life was spent long before the material arrived at our laboratories and consequently the decay curve yielded a straight line curve in accordance with the mathematical equation. If a mixture of two radioactive isotopes is examined immediately upon removal from the cyclotron, the deviation from straight line is readily apparent. For example, the curved line in Fig. 3 represents some experimental data for a freshly activated sample. In about an hour and a half it assumes linearity. The asymptote Line I, projected to the left, represents conditions for the longer lived isotope (or isomer). Inspection of this line indicates that the major portion has a half-life of 105 min. (An activity of 2000 counts per min., point m, had dropped to 1000 per min. at point n, 105 min. later.)

The distance the experimental curve lies above Curve I represents activity of the second isomer. Its individual activity can be plotted by difference; eq. at 20 min. $p = 3000$ and $q = 1685$; $p - q = 1315$, which is the location of point r. A similar series of plots gives Curve II, from which the half-life of the second isomer is found to be 13.9 min. As Curve II is a straight line, it indicates radiation from a homogeneous portion; if it were curved, it would be evidence that a third portion existed, and the line could be again analyzed as already indicated.

Condition of Sample — A sample can be in any one of the three forms of matter — gaseous, liquid, or solid. The last two are the common forms used in metallurgical tracer analysis.

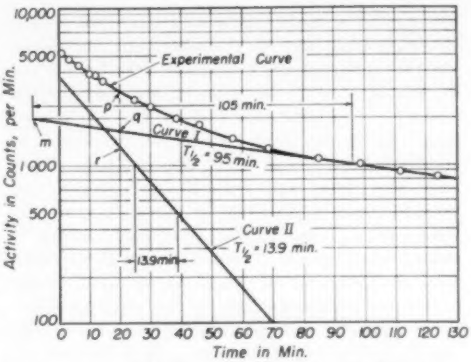

Fig. 3 — Experimental Curve for Radioactive Mixture — Two Portions of Different Half-Lives

Liquids have the advantage of uniform distribution of the radioactive particles, but most of the beta rays are absorbed by the solvent. Special thin-walled Geiger tubes counteract this, in part. While a great many test samples are in the solid form, they possess difficulties originating in the geometry of the form and absorption of radiation within the sample.

Sample Geometry — Any form of the sample which will give quantitative and reproducible results may be used,[9] either powder, solution, thin film, plane or other reproducible surface. Selection of a proper sample is the critical step in any tracer analysis. Fortunately it is also the major step which can be controlled to fit the existing experimental conditions. The two main sources of error arising from poor geometry will now be briefly discussed.

When a radioactive sample decays it shoots off particles in all directions. Thus the locus of disintegration effects from a small sample is a sphere about that particle. If such a sample is brought near a Geiger tube, only that portion of the emitted particles can be registered which falls within the solid angle subtended by the tube's window. This depends on the size of the tube and the distance of the sample, as shown in Fig. 4. The ratio of the particles reaching the tube to the whole number given off by the sample is called the "solid angle" or the "geometry" of the arrangement.

In practice, the source cannot be considered as a point, since solid or liquid samples possess a finite volume and cross-sectional area. The geometry of such a real system[10] is given by the following equation:

$$\left[1 - \frac{1}{\sqrt{1+\alpha}} - \tfrac{3}{8}\,\alpha\,\rho\,\frac{1}{\sqrt{(1+\alpha)^5}} - \ldots\ldots\right]$$

In this equation $\alpha = b^2/a^2$

$\rho = c^2/a^2$

a = distance, sample to tube face

b = radius of tube window

c = radius of sample

According to this equation, the only variables affecting the solid angle are the area of the face of the Geiger tube, the distance of the sample from the tube, and the area of the sample. The diameter of the tube and the distance of the sample from the tube (in a unit employing a stationary set of shelves) are constant for any one series of tests and in that event the only variable to consider is the area of the sample. We have therefore used the equation to determine the permissible variation in the sample size without introducing an appreciable error.

Assume a sample 0.5 in. diameter placed 0.813 in. from a Geiger tube with face 1.5 in. diameter. The quantities needed to figure the geometry are

$a^2 = 0.661$
$b^2 = 0.562$
$c^2 = 0.062$
$\alpha = 0.85$
$\rho = 0.094$

Substituting these values in the equation for geometry we have the value 12.43%.

Suppose that the sample is $\frac{9}{16}$ in. in diameter rather than ½ in., as intended, the geometry would be 12.35%, a difference of 0.08 unit or −0.6% of the standard. Again, a sample ⅝ in. diameter would introduce an error of −1.4% in the counts from identical material of standard size.

Similar computations show that the error from geometry decreases with an increase in distance, sample to tube. For example, when the sample was placed on the lower shelf in our apparatus (a = 1.437 in.), a sample ⅝ in. in diameter rather than the standard ½ in. introduces an error of only −0.2%.

With care, we were able to control the diameter of the sample to within $\frac{1}{16}$ in. and as such this introduced a maximum variation of about 0.6% due to geometry. While increasing the distance between the tube and the sample decreases the error, if an isotope has sufficient activity to yield a minimum of 40,000 counts in a reasonable time the use of increasing distances is desirable (health requirements permitting). The data on the tests given in the latter part of this paper were obtained by using the shorter distance in our set-up.

The second major cause for the loss of activity from a radioactive sample is absorption of the emitted particles or radiation. In traveling from the sample to the tube, the particles or rays lose energy. In consequence, only a portion of the original particles within the solid angle enter the tube and are counted. The amount of absorption occurring will depend upon the type of particle emitted (β or γ ray) and upon the physical state and character of the matter through which these particles must pass. In the Geiger assembly, absorption occurs in the mica window of the tube (solid material), in the air between the sample and the tube (gas), and within the sample itself (liquid or solid).

The first two sources of absorption are constant, provided the sample is the same distance from the tube in each test, and can be neglected because an absolute count is unnecessary in metallurgical work. The only requirement is that the particle's energy be sufficient to penetrate the air and the window.

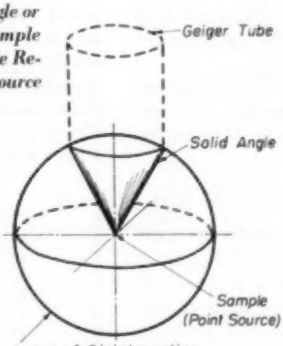

Fig. 4 — Solid Angle or Geometry of a Sample Small Enough to Be Regarded as a Point Source

However, surface absorption and self-absorption must be controlled under as close limits as possible. If the particles of the radioactive sample are of the same size and evenly distributed on the surface of an inert holder, the loss of emission by self-absorption between adjoining particles will be a constant value which does not affect the final results of a relative analysis. If the sample is made up of more than one layer of powder, surface absorption of emission from the underlying layers further decreases the activity.

This cumulative loss results in the absorption curves shown in Fig. 5. The different slopes of the tangent portions of the curves are caused by a decrease in the solid angle as the distance between the tube and the sample increases. The departure from a linear path is in each instance a result of the self-absorption of the emitted rays.

The flattening trend of curves C, D and E indicates that, after a certain number of layers have been built on, no further activity is obtained by increasing the sample weight (thickness) because of the complete self-absorption of the emanations from the underlying material. Such curves vary in position according to the distance sample to tube and the energy of the particular particles emitted.

Almost all particles from available radio-

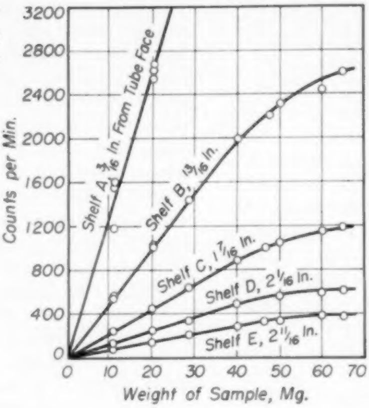

Fig. 5 — Observed Activity of Co^{60} as the Thickness (Weight) of Sample Increases

active atoms have an energy of 2 to 3 Mev. (million electron volts). Beta particles from those few isotopes which are strong beta emitters are absorbed exponentially in solids — the range being of the order of a few millimeters. The low-energy particles (less than 0.8 Mev.) are absorbed much more readily. The equation for their absorption in aluminum is, for example, $R = 0.407\,E^{1.4}$, where the range is expressed in grams per square centimeter (that is to say, the thickness of 1 sq.cm. of aluminum that weighs a given number of grams), and E is the average energy of the beta particles in millions of electron volts.

The gamma rays are far more penetrating than beta particles of high energy, and are absorbed exponentially according to the equation at the top of the next column.

$I = I_0^{-\mu x}$, wherein

I = intensity at any distance x
I_0 = initial intensity
x = distance from source (cm.)
μ = relative loss of intensity per cm. of path (the linear absorption coefficient)

To determine the extent of these factors, the following tests were conducted:

Powder Sample With Cellophane Cover — The thin turnings from the plated steel cylinders already mentioned were ground to −35 mesh, weighed, and placed in a cardboard holder containing a shallow cylindrical hole ($\frac{7}{16}$ in. diameter and ⅛ in. deep). A sheet of cellophane was placed over the opening and the assembly sealed with scotch tape. Only about one fourth of the hole was filled with the powder. A number of determinations were made on each sample, the sample being mixed by shaking after each determination to insure maximum variation in both geometry and absorption. The results of these tests showing the range of values obtained are presented at the left of Fig. 6. The error arising through statistical variation is a minor factor when the geometry and absorption are not controlled.

Counts per minute were converted to atomic per cent by analyzing a sample of the as-plated material; the latter equals 100%. Other values were determined by direct ratio.

Powder Sample Without Cellophane Cover — The same samples used in the above tests were re-employed. Turnings from each layer were divided into a number of smaller portions and placed in the same type of holders, which were then sealed with scotch tape. The card was inverted, whereupon the powder stuck to the tape, and it could be removed and placed on the shelf face up below the counter.

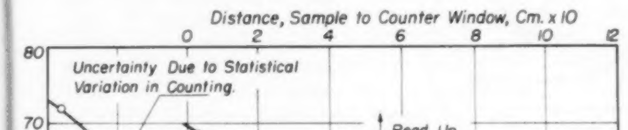

Fig. 6 — Tests on Radioactive Cobalt Electroplate at Various Distances From Counter Tube Window. Left: Ground chips under cellophane cover. Center: Ground chips with no cover. Right: Cobalt in HCl solution

Results of these tests are shown in the center of Fig. 6. Except for the portions of the curves at distances lower than 3 cm. the two sets are identical, within experimental error. In these tests without cover, absorption of the radiation is also a major source of error. Calculated error due to geometry is about 2% of the counts recorded. The range of the beta particles emitted from Co^{60} is about 0.11 mm. Since the 35-mesh particles are 0.417 mm. in diameter, only those emitted near the surface of the outermost layer reached the tube. As in the other tests, only those particles from the uppermost layer reached the tube, the others being absorbed within the sample itself.

It would appear, therefore, that powder analysis should be limited to experiments on friable material that can be easily crushed to a small mesh size. Ductile materials will produce flakes of various thicknesses, causing excessive error in counting because of uncontrolled absorption of normal radiation.

Table II — Analyses of Thin Film Samples

Sample No.	Counts*	Atomic % Cobalt	Distance from Surface
1	46.6 46.5	41.0 40.8	2.92 cm.
2	38.7 38.6	34.0 33.9	4.20
3	27.2 27.0	23.8 23.7	5.09
4	8.91 8.89	7.83 7.80	6.40
5	4.07 4.13	3.58 3.63	7.68
6	1.51 1.48	1.32 1.30	8.95

*Counts per min. per mg. of cobalt.

Liquid Sample — To measure approximately the error due to such self-absorption, some of the samples were dissolved in hydrochloric acid. To prevent evaporation the small containers were capped with thin mica sheets. The cups were then placed under the Geiger tube and the same analysis conducted as for powder. Results are shown at the right of Fig. 6. The maximum variation is only 4%, as compared to 17% and 10% respectively in the two former tests. However, even though the absorption and geometry are closely controlled, the resultant counts per sec. are so low that statistical fluctuations offset the advantages obtained. Special Geiger tubes, with thin walls, immersed directly into the solution, or tubes around which a solution can be passed, are necessary to obtain satisfactory solution analyses. Such equipment has given excellent results for various investigators.

Thin Film — Samples weighing 40 mg were taken into solution with 1 ml. of 6n HCl. Four to six drops of this were transferred to a thin glass slide, previously weighed. The plates were then dried at 110° C. for 60 min., placed in a desiccator and cooled at least 2 hr. before re-weighing on a balance accurate to 0.05 mg. Counting then began.

Results of testing such samples are given in Table II. Under the condition of controlled geometry and absorption very accurate results were obtained from samples with sufficient radioactivity.

Coincidence Counting — When an elementary particle enters the interior of the Geiger tube, it ionizes molecules of the gas and these (in addition to the freed electrons), under an applied potential, cause new ionization which ultimately builds up sufficiently to discharge the tube. The period between the discharge and the time the tube is capable of starting another cycle is termed the "dead time". Any particle that enters the counter during this time is not counted and these misses are termed "coincidences", and the counting rate must be corrected for these misses. The corrections in counts per minute for beta particles for a typical Geiger tube are given in Table III up to 1000 counts per min.

Table III — Corrections for Coincidence Counting

Range of Counts Recorded	Correction in Counts per Min.
0 to 204	0
205 to 354	1
355 to 455	2
456 to 539	3
540 to 612	4
613 to 677	5
678 to 735	6
736 to 791	7
792 to 842	8
843 to 889	9
890 to 935	10
936 to 978	11
979 to 1000	12

Health Requirements

The lower limit of activity which can be used in a tracer analysis is determined by the magnitude of the uncontrollable fluctuations, such as background and the other matters discussed above. If the activity could be increased to any desired amounts, these fluctuations could be reduced to an inconsiderable proportion. However, the uncertainty of the effect of radiation on body tissue limits the maximum activity which may be used.

The specifications and general rules for the maximum activity to which one may be safely exposed are given in detail in the Atomic Energy Commission's bulletin on "Rules and Procedures Concerning Radioactive Substances and Associated Hazards". The activity used in the current experiments was considerably below the limits specified in that publication.

Isotopes — A few of the isotopes which are available from the Isotopes Branch of the Atomic Energy Commission are listed below:

Isotope	Half-Life
Carbon 14	5720 years
Phosphorus 32	14.3 days
*Sulphur 35	87.1 days
Calcium 45	180 days
Chromium 51	26.5 days
Cobalt 60	5.3 years
Copper 64	12.8 hours
Gold 198	2.7 days
Iron 55	4 years
Molybdenum 99	68.3 hours
Nickel 59	16 years
*Palladium 103	17 days
Silver 110	282 days
Titanium 51	72 days
Tungsten 185	74 days
Zinc 65	250 days
Zirconium 95	63 days

*Contains radioactive impurities.

Conclusion

A number of variables must be considered by the experimenter in conducting a radioactive analysis. In this paper these variables have been examined under various conditions to determine the accuracy necessary to obtain reproducible results.

The method of obtaining samples introduced no error, since only the reproducibility of values within each particular concentric layer of a plated cylinder was used as the basis of comparison. This eliminated any error caused by variation in temperature, or measurement of the thickness of any layer during the preparation of the initial sample. Of the various methods, the thin film samples yielded the most concordant results. Under different experimental conditions, the other methods may serve excellently.

A summary of the variables which must be controlled and the experimental limitations encountered are given in Table IV.

Table IV — Summary of Variables

Variables	Methods for Decreasing Error	Experimental Limitations
Background	Indirect: Increase activity of sample, or Increase size of sample	Nature of cosmic rays; Lead housing
Activity of sample	High activity causes less relative fluctuation	Health requirements
Form of sample	Any reproducible geometric form	None, if equipment available
Weight of sample	Increased weight	Upper linear portion of absorption curve
Solid angle (geometry)	Uniform area	For finite areas, the equation should be a converging series
Absorption	Uniform thickness; Same distance from tube	Energy and type of particle

Acknowledgments—The authors are pleased to acknowledge their indebtedness to J. Hugh Hamilton, director of the Utah Engineering Experiment Station, for providing the funds which made this work possible, and to the University of Utah Research Committee (through the University's department of physics) who made the radioactive equipment available.

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ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

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How CHROMIUM and TUNGSTEN Increase Strength of High-Temperature Alloys

The aircraft field has served as an important "proving ground" for the high-temperature alloys that have been developed for gas turbines required to operate at elevated temperatures. However, these alloys are now demonstrating their superior properties for other primary power applications, including gas turbines to operate electrical generators for stationary or motive power.

While there are literally dozens of different alloys available for high-temperature use, most of them contain the alloying elements chromium and tungsten for the express purpose of enhancing resistance to scaling and increasing their hardness and strength at elevated temperatures. The amount used is generally determined by the stresses and temperatures expected in service. Other alloying metals may also be added for special purposes — such as columbium, manganese, silicon, and titanium.

Chromium and Tungsten as Strength-Builders

Even small amounts of chromium and tungsten are effective in increasing the strength of high-temperature alloys. An important consideration is, of course, the exposure time—particularly when operating temperatures go above 1200 degrees Fahrenheit. Although the major role of chromium is to prevent scaling, it has been found that chromium, as well as tungsten, also helps the alloys to maintain their strength when they are exposed to high temperatures for long periods of time.

In addition to chromium and tungsten, the combination of other alloying metals present will likewise influence the strength of the alloys. Heat-treatment, too, will influence the properties of these materials. However, in obtaining the higher ranges of strength needed at extremely high temperatures, chromium and tungsten are essential.

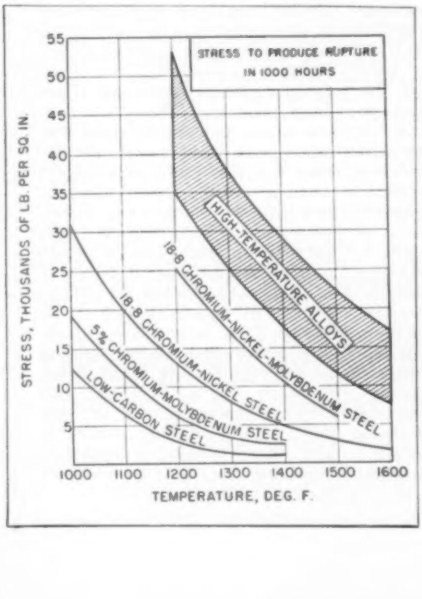


Fig. 1—Here is the average range of strength of various high-temperature alloys compared with other metals.

Where High-Temperature Alloys Are Used

Special high-temperature alloys containing chromium and tungsten are being used for the construction of gas turbines that power railroad locomotives, ships, airplanes, and electric generating plants. Some typical parts made of these alloys are rotors, turbine blades, nozzle vanes, ducts, and housings. These parts are exposed to temperatures of from 1200 to 1500 degrees Fahrenheit.

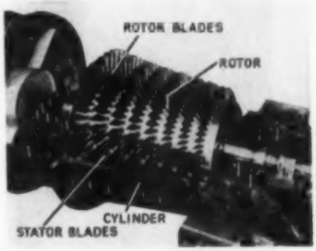
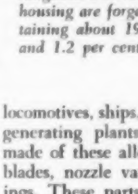


Fig. 2—Rotor and stator blades in this locomotive-type gas turbine are precision-cast of an alloy containing about 24 per cent chromium and 6 per cent tungsten. The rotor body and cylinder housing are forged from an alloy containing about 19 per cent chromium and 1.2 per cent tungsten.

If You Need Technical Help

Those producing high-temperature alloys who wish technical help in the selection of alloying metals will find ELECTROMET's metallurgists glad to co-operate. In addition to chromium and tungsten alloys, ELECTROMET also produces ferro-alloys of columbium, manganese, silicon, and titanium for use in making high-temperature alloys. If you wish further information about the properties and uses of these alloys, write to the nearest ELECTROMET office.



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Personal Mention

Raymond H. Schaefer

Bernard R. Queneau

Lillian R. Bauer

Raymond H. Schaefer ⊕, who has been with the American Brake Shoe Co. for the past 11 years, has recently been elected vice-president of the company. He graduated from Carnegie Institute of Technology in 1934 and remained there in the metals research laboratory until early in 1935 when he joined International Nickel Co.'s metallurgical research laboratory in Bayonne, N. J. He came to American Brake Shoe Co. in 1940 as assistant foundry metallurgist of the company's American Manganese Steel Division, Chicago Heights, Ill., and was successively foundry metallurgist and general foundry superintendent. In 1943, Mr. Schaefer was transferred to American Brake Shoe Co., Mahwah, N. J., as assistant chief metallurgist, later becoming chief metallurgist. Since much of the production is gray iron castings, extended studies have been made in the company's fine experimental foundry on this ancient and neglected metal, a good part of it under Raymond Schaefer's direction. The experimental foundry also studies sand and other molding materials, parts cast in centrifugal equipment, and the hardening transformations in both plain and alloyed steels. In 1947 Mr. Schaefer was appointed director of research and development, and will continue in charge of the research activities of the company.

Bernard R. Queneau ⊕, whose original contributions to metallurgical literature include papers on the determination of solubility limits of the nickel-chromium system, austempering of case carburized parts and hardenability of alloy steels, has had a versatile metallurgical career. After graduation from Columbia University in 1933 he spent three years as an assistant in the School of Mines, University of Minnesota, where he also received his Ph.D., and a similar time at Columbia University as assistant professor of metallurgy. Called for active duty in the Navy in 1941, he was assigned to the U. S. Naval Proving Ground at Dahlgren, Va., where his many contributions to the development of improved armor plate and armor piercing projectiles earned him a ribbon and a letter of commendation from the Secretary of the Navy. In 1946, Dr. Queneau returned to industrial research as chief development metallurgist at the South Works of Carnegie-Illinois, where he handled such unrelated projects as the development of the turbo-hearth, the all-basic openhearth furnace, and corrosion resistance of extra low-carbon stainless steels. His recent promotion to chief metallurgist at the Duquesne Works of United States Steel Co. gives him charge of process control of melting, rolling, finishing, and steel inspection.

Among the 20,000 members of ⊕ (give or take a few hundred) are to be found about 0.1% women. The males among the membership have come to recognize the unusual merit of these ladies — "stature" is the customary word but is hardly a gallant one to apply to femininity. Since metallurgists are direct descendants of blacksmiths — "mighty men" — it seems a bit incongruous to find women among them, and to compete they must have, and obviously do have, a lot above their shoulders. Lillian R. Bauer is one of these notable women. Her husband, the late Dale W. Bauer, was one of the founders and first secretary of the Steel Treating Research Society of Detroit, active in its local affairs and its expansion to 1070 members between 1915 and 1920, and when it eventually became one of the two groups which, merging, formed the ⊕. Consequently, Mrs. Bauer heard metallurgy discussed at the breakfast table. More than that, she was a salesman (excuse it — saleswoman) in girlhood. Her father, Joseph Reynolds, was general manager for the Detroit Electric, and she sold cars to many women who couldn't see why they should not drive an automobile. So it was no trick at all for her to take over her husband's business, the Libbey-Bauer Co., representing W. S. Rockwell Co. in Michigan, which, as all readers of *Metal Progress* and its advertising pages know, makes furnaces, ovens, pickling and cleaning equipment, and rod and wire mill machinery. Logically, also, she retained her husband's useful membership in the American Society for Metals.

Personals

Raymond B. Ziccarelli is employed by Boeing Airplane Co., Seattle, Wash., as an engineer in the welding group of the process and standards unit.

Martin J. Lyons has been promoted from time and methods supervisor to process engineer at the John Wood Co., Ltd., Winnipeg, Manitoba, Canada.

Fred B. Smith has been recalled to active service as a captain in the Ordnance Corps and is assigned to the Ordnance Rocket Center, Redstone Arsenal, Huntsville, Ala., as chief of Test and Evaluation Branch. He is on leave from his position as senior research engineer, Armour Research Foundation, Chicago.

Henry F. Keller, Jr.,, has been employed by the Caterpillar Tractor Co., Peoria, Ill., since his graduation from Purdue University, June 1950.

Donald A. Campbell was recently appointed vice-president in charge of engineering and research for Eclipse Fuel Engineering Co., Chicago.

Harry L. Edgcomb, Jr.,, and **Ralph W. Shaw, Jr.,**, have been elected president and treasurer, respectively, of the board of directors of the National Association of Aluminum Distributors, and **J. J. Hill** has been named a director.

Thomas G. McNamara, formerly chief metallurgist at Continental Aviation and Engineering Corp., Detroit, has been appointed chief metallurgist for Alloy Engineering and Casting Co., Champaign, Ill.

Robert M. Buck has been named manager of Bryant Heater's Industrial Division, Cleveland.

L. W. Bosch has been promoted from superintendent of quality control and inspection, Imperial Works, Oil Well Supply Co., Oil City, Pa., to manager of quality control covering all plants of the company.

Michael M. Boros is president of the newly-organized Tool Steels Inc., Cleveland.

Albert J. Belli is a metallurgical engineer with Wright Aeronautical Co., Wood-Ridge, N. J.

Einar Iverson has been employed as a welding engineer by Worthington Pump and Machinery Corp., Harrison, N. J.

John Billings has accepted a position with the A. V. Roe Co., Canadian aircraft manufacturers, as a metallurgist.

Ernest L. Blodgett, formerly employed as superintendent of the heat treating department at Reece Corp., Waltham, Mass., is now the proprietor of the Hotel Alstead, Alstead, N. H., and will do consulting work in that area.

W. J. Resiner has been granted a leave of absence from Republic Steel Corp. to act as commodity industry analyst with the Steel Pipe and Tube Section of the National Production Authority, Washington, D. C.

L. J. Demer has resigned as assistant professor of materials engineering at Syracuse University and accepted a position as research associate in the Engineering Experiment Station, University of Minnesota, Minneapolis.

Personals

H. W. Zieler ⊕ has recently become associated with W. H. Kessel and Co., Chicago, distributors of scientific instruments.

Franz R. Brotzen ⊕ has transferred from the Bureau of Mines, Washington, D. C., to Case Institute of Technology, Cleveland, where he is a research associate in the metallurgical department.

Edward P. Patterson ⊕, formerly an instructor at National School of Aeronautics, Kansas City, Mo., has been employed as a metallurgical engineer by Boeing Airplane Co., Wichita, Kan.

John Varga, Jr., ⊕, is now employed by Battelle Memorial Institute, Columbus, Ohio, as a research engineer.

William A. Bostrom ⊕ has been placed in charge of the radiation counting laboratory and pyrometric standards laboratory of the Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh.

George J. Thompson ⊕ is a metallurgist assigned to the blast furnaces at Pittsburgh Steel Co., Monessen, Pa.

Keith V. Davidson ⊕ has been employed as a chemist by the Globe Plant of American Smelting and Refining Co., Denver, since his graduation from Colorado School of Mines last June.

Roger D. Moeller ⊕ resigned his position of staff member of Los Alamos Scientific Laboratory to take a position as research engineer in the Atomic Energy Research Department at North American Aviation, Inc., Downey, Calif.

Fred E. Weisser ⊕ is now associated with the New Departure Division of General Motors Corp., Bristol, Conn., as a metallurgist.

G. William Eggers ⊕, June 1950 graduate from the University of Notre Dame, is now associated with Phillips Petroleum Co., Bartlesville, Okla., in the Test Division of the engineering department.

Robert A. Powell ⊕ has been employed in the metallurgy department of Jones & Laughlin Steel Corp., Pittsburgh, since his graduation from University of Pittsburgh, September 1950.

Personals

Ernest W. Brix ⊕ has resigned his position as chief design engineer on die castings, dies and tools, Advance Pressure Castings, Inc., Brooklyn, and is now superintendent of die casting at Hampden Brass and Aluminum Co., Springfield, Mass.

Roger A. Perkins ⊕ has been employed as a research trainee with Union Carbide and Carbon Research Laboratories, Inc., Niagara Falls, N. Y., since his graduation from Purdue University in January.

William H. Johnson ⊕ is now a metallurgist with the Naval Research Laboratory, Washington, D. C.

Eugene M. Stein ⊕ has taken a position as principal metallurgist at Battelle Memorial Institute, Columbus, Ohio.

Alan F. Busto ⊕ has been employed as a welding technician at International Harvester Co., Manufacturing Research Division, Chicago, since his graduation from the University of Michigan in June 1950.

H. B. Emerick ⊕, formerly assistant plant metallurgist at the Aliquippa Works, Jones & Laughlin Steel Corp., is now assistant to the vice-president in charge of technology.

George A. Barker ⊕ has been named a consultant to the National Production Authority, Iron and Steel Division, ferro-alloys and metals sections, Washington, D. C.

Earl R. Cunningham, Jr., ⊕, is a shift metallurgist at Crucible Steel Co. of America, Sanderson-Holcomb Works, Syracuse, N. Y.

William P. McKinnell, Jr., ⊕, formerly with the Engineering Division, Chrysler Corp., has accepted a position as assistant professor of metallurgical engineering at Virginia Polytechnic Institute, Blacksburg, Va.

Ralph C. Seikel ⊕ is now foundry foreman, New Haven Foundry, New Haven, Mich.

Charles R. Cook ⊕ has been recalled for extended active duty with the Army Corps of Engineers. Lt. Cook is at present assigned to the Post Engineer Section, Fort Holabird, Md.

Turbine Alloys

(Continued from p. 656) a figure which could be tolerated by mechanical design allowances. The aging process reduced the creep strength by about 10%, but the general balance of properties was considered to be improved. An attempt to avoid loss of creep strength — if possible to enhance it — as well as to raise the proof stress resulted in a long research that led to a process, known as "warm working", which confers quite remarkable mechanical properties at low and high temperatures upon certain austenitic steels, and G18B has proved to be most responsive. The growth on disks subjected to this treatment was reduced to the very low figure of 0.001 to 0.003 in. The low creep rate at 26,900 psi. and 650° C. (1200° F.) shown in the bottom line of Fig. 3 persists for at least 6000 hr., at which time the total strain from creep would reach about 0.4%.

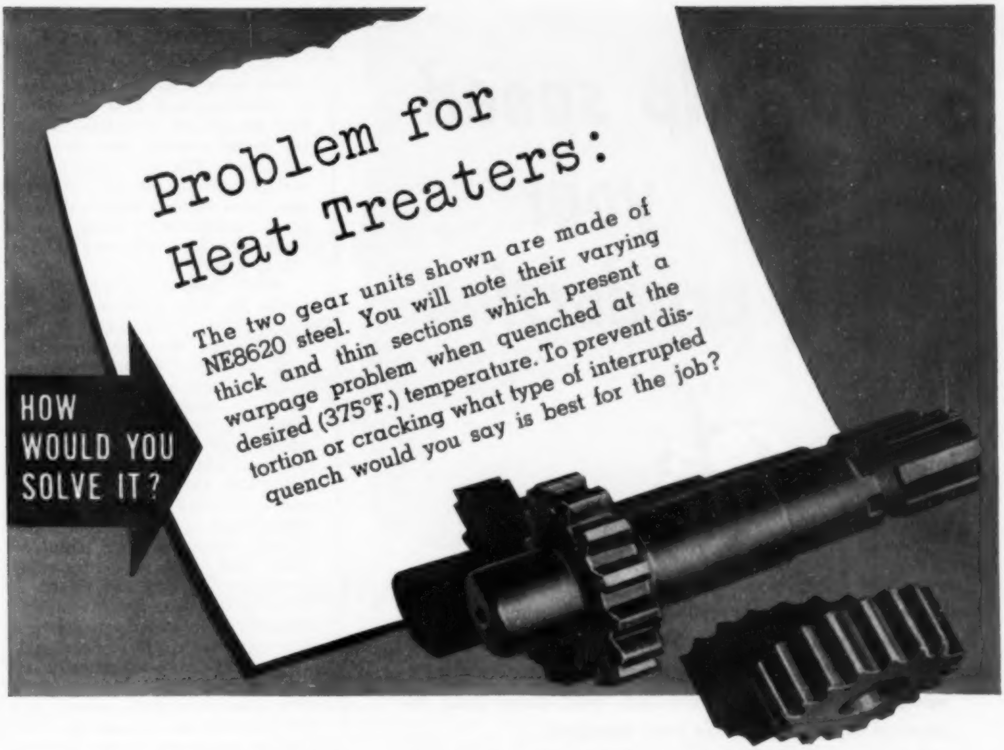
In production — following solution treatment at 1300° C. (2370° F.) and any subsequent machining that is required — G18B turbine disks are heated at 700° C. (about 1300° F.) in a gas-fired furnace for "warm working" and, after an adequate soaking period, are transferred to a 10-ton drop hammer, the largest readily available. The disks are given a small number of blows, and the reduction in thickness is measured. This procedure is applied to disk forgings which are "warm worked" either between flat tools or in dies. A great many disks have been manufactured in this way and, although the process must be strictly controlled, it has given uniformly good properties and satisfactory use under the most severe conditions in flight.

It appears that one of the main problems is to provide a hammer of sufficiently large capacity for working some of the larger disks. This has been overcome in part by "warm working" the central region only, and doubtless many turbine disks will be so fabricated in the future. Of course, the process should not be regarded as applicable only to turbine disks; for instance, "warm rolling" of bar material is effective and would be suitable for rectangular sections intended for turbine blades, and for other high-temperature applications in other fields.

Austenitic Alloys With Columbium

The bulk of the data recorded in the paper "Studies of the Properties of a Chromium-Nickel-Niobium★ Steel", by H. W. Kirkby and C. Sykes of the Brown-Firth Research Laboratories (Sheffield) refers to bar material, air cooled from 1050° C. (1920° F.). It has the following composition: 0.11% C, 0.50% Si, 0.41% Mn, 9.5% Ni, 17.84% Cr, 1.22% Cb. The creep data, together with the supplementary information given on forgings, indicate that the strength of such a steel is adequate for the many applications such as rotor forgings, blades, and tubes up to 625° C. (1160° F.). At 1200° F. and above, the creep strength falls away rapidly for long-term applications such as 100,000 hr. Both mechanical and metallographic tests after exposure at elevated temperatures indicate that little or no austenite has transformed if the nickel content is between 9 and 13%. In addition, the small amount of sigma phase which slowly appears is insufficient to cause any significant *(To p. 692)*

★TRANSLATOR'S NOTE — The British use "niobium" where the Americans would say "columbium".



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Turbine Alloys

(Cont. from p. 690) deterioration in ductility, and it is interesting that its amount is independent of the nickel content over the range examined. The mechanical tests carried out on the various creep specimens indicate that a minimum of 1% extension in creep can be assumed before intercrystalline cracking occurs.

Work carried out on "Special Steels for Gas Turbines" by the United Steel Companies Ltd. was described by W. E. Bardgett and G. R. Bolsover. Their paper deals primarily with a multi-alloy "steel" containing about 45% nickel, 20% chromium, 2.7% molybdenum, 3.3% cobalt, 3.0% columbium, 3.5% tungsten, and 1.2% titanium. Data are given both for creep and for general mechanical properties after different amounts of hot work, tested both transversely and longitudinally. The results show little effect of either direction or amount of work on the essential properties. Properties are also presented of a 25% chromium, 15% nickel-type steel, suitable for combustion chambers. An alloy containing about 20% chromium, 30% nickel, and 1% titanium, also suitable for combustion chambers, shows remarkably good creep resistance at 650° C. (1200° F.).

Hot Fatigue Testing

Apparatus designed and constructed for the investigation of the fatigue strengths of materials at elevated temperatures was described by H. E. Gresham and B. Hall of Rolls-Royce, Ltd. (Derby). Collets for holding the test pieces are made of an austenitic steel whose life is limited by the loss of accuracy of fit by scaling. Up to 500° C. (930° F.) tests adding up to many thousands of million reversals can be run without trouble, but in the 700 to 800° C. range (1300 to 1470° F.) where oxidation is more serious, the life of the collets is considerably reduced. Even then, 10 to 12 runs can be completed satisfactorily.

Alternative and improved materials with higher scaling resistance are being tried, and it is hoped to extend the testing temperature to 950° C. (1750° F.). In this work, simple tests in alternating bending have been carried out continuously to obtain basic data for design purposes. Fatigue under corrosive con-

(Continued on p. 694)

Turbine Alloys

(*Continued from p. 692*)

ditions — for example, by sulphur gases, lead compounds, and salt spray — has also been examined.

A further new development in the testing of gas-turbine materials is an electronic fatigue machine, designed to vibrate a specimen with rectangular section at much higher frequencies than attained with more conventional equipment. The drive is obtained from a moving coil fed from an oscillator, synchronized by feedback from a photo-electric cell illuminated by a light beam crossing the specimen. In principle, the mechanism resembles that used in the moving coil loud-speaker.

Tentative results on the effect of a cold worked surface on the fatigue strength of turbine blades have already been obtained. Cold working of the surface causes no appreciable reduction in the hot fatigue strength of Nimonic 80A when the mean stress is zero, but it reduces the fatigue strength when the material is subjected to creep stresses before fatigue testing.

Sintered Alloys

A cobalt-base alloy of the Vitallium type (containing 64% cobalt, 30% chromium and 6% tungsten) has been made by powder metallurgy methods. A comparison of the properties to be expected from this alloy prepared by a straightforward sintering process and a similar cast alloy was made by R. W. A. Buswell, W. R. Pitkin and I. Jenkins of General Electric Co., Ltd. (Wembley). They find that a product having very low porosity can be obtained in the absence of a liquid phase during sintering, provided the powder characteristics are suitable and that adequate control is maintained over the sintering conditions. The room-temperature properties of the sintered product compare favorably with those of the cast alloy; at high temperatures, although the fatigue properties of the sintered material are encouraging, the creep properties, at least above 600° C. (1110° F.), are comparatively low.

Improving the high-temperature strength by the introduction of refractory oxides such as thoria is a possibility. The low strength in creep may be associated with the absence of the intergranular carbide networks found in the cast alloy,

(*Continued on p. 696*)

Turbine Alloys

(Continued from p. 694)

and methods of introducing carbon into the sintered alloy could be devised. The sintered alloy is apparently quite amenable to heat treatment.

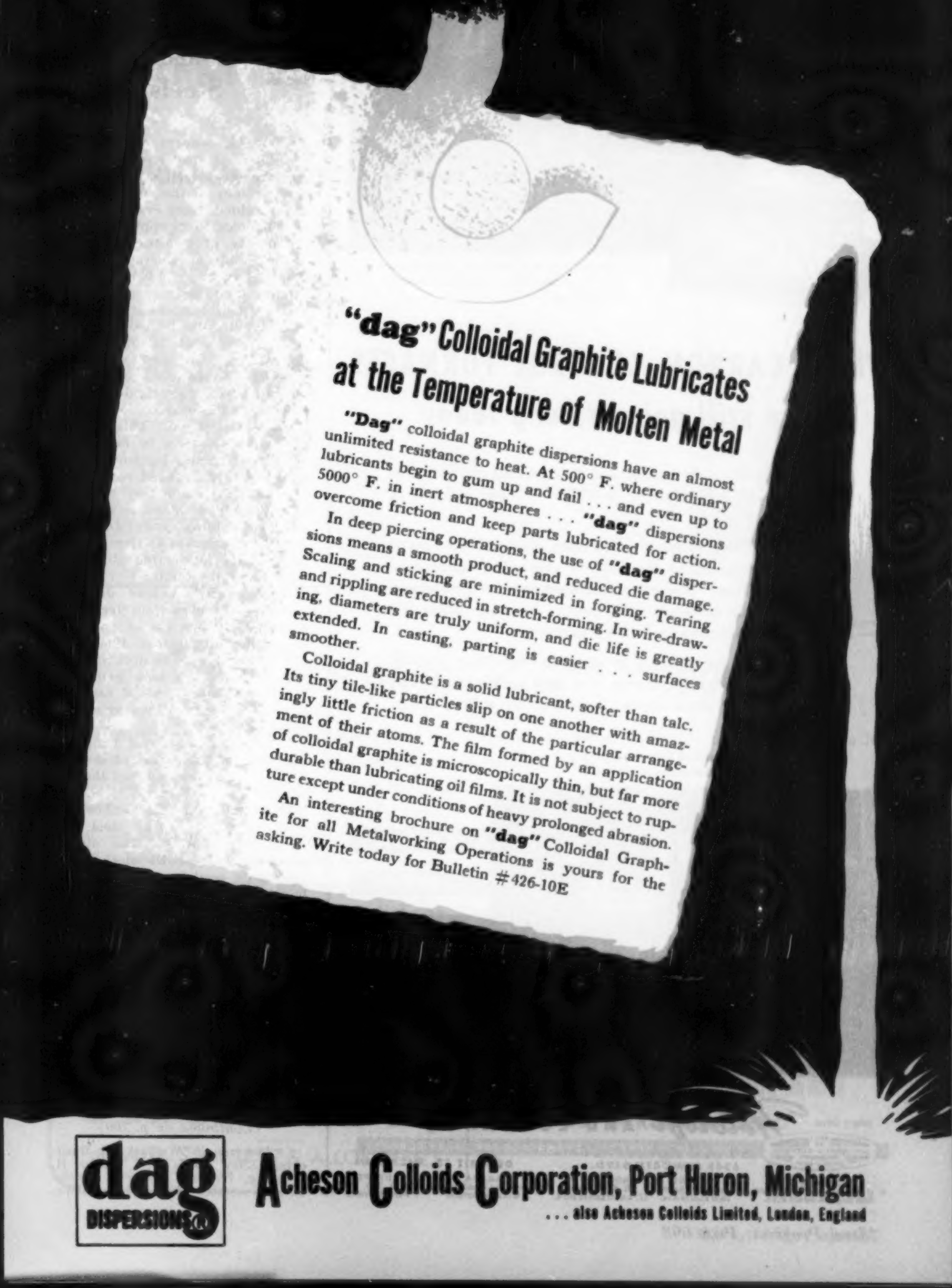
Future Needs

Appropriately enough, the final papers in this notable symposium were on future possibilities — one by C. A. Bristow and H. Sutton of the Ministry of Supply entitled "Research and Development on High-Temperature Materials" and the other by J. M. Robertson of C. A. Parsons & Co., Ltd. (Newcastle-upon-Tyne) entitled "Future Needs in Materials for Land and Marine Gas Turbines".

The first of these papers considered problems posed by the relatively short supply of the most valuable metallic elements for making the refractory alloys now recognized. This indicates the need for the utmost economy in their use. Researches now under way in Great Britain on numerous ternary systems were listed, and the hope was ventured that such metallurgical research might lead to valuable generalizations on the "design" of creep resistant alloys. It is known, for example, that quite small amounts of chemical compounds have vastly disproportionate effects on the properties of solid solution alloys.

Lines for expected further advances are in sintered bodies (metal and oxide, carbide, or boride), reduction of maximum temperature in the engine by design, and surface protection of refractory but chemically active metals.

Dr. Robertson pointed out that, despite present operation of about 100 gas turbines in service other than aircraft, the designs and requirements are so various that the future metallurgical needs can hardly be appraised until the demands are somewhat stabilized. He looks for new alloys to be developed in stainless and nonstainless ferritic steels, in age hardenable and heat treatable austenitic alloys (iron base), in alloys based on nickel and cobalt, on chromium, on molybdenum, and perhaps on titanium. Future advances will depend upon such an important engineering consideration as reliability (margin of safety) and the commercial consideration of cost (both of metal and of fabrication).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Welding Air Hardening Steels*

GENERAL concept of the weldability of steel envisages some measure of evaluation in terms of the tendency of the steel to crack when welded. Such evaluation usually includes, in its appraisal of the probability of producing sound welded joints, consideration of certain factors of joint welding procedure, joint design, cooling rate and ambient temperature. Unfortunately, it often happens that results of small-scale laboratory tests do not correlate well with field welding performance, particularly where considerable rigidity is developed in the structure because of its size and shape. This lack of correlation appears to be heightened by increasing hardenability of the steel used in the structure.

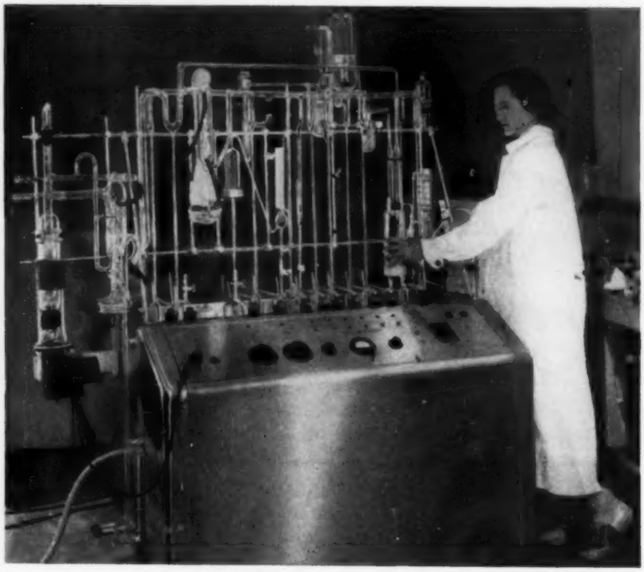
The "Navy Patch Test" was used in the study designed to establish suitable welding procedure for nickel-chromium-molybdenum steel plate in the fabrication of a large rigid structure similar to one previously erected without difficulty using a nickel-chromium steel plate. This test permits use of materials of greater dimensions than normally encountered in ordinary laboratory tests and also provides means for adjustment of restraint across the welded joint over a wide range of values.

The quenched and tempered (Brinell 200-230) steel plate used was 3¾ in. thick and had the following composition: C 0.42, Mn 0.38, Si 0.15, Ni 3.60, Cr 2.30, Mo 0.43, Va 0.01%. This steel was designated Type A. The nickel-chromium (Type B) steel plate previously used for the fabrication had the same temper and hardness and the following composition: C 0.30, Mn 0.21, Si 0.05, Ni 3.22, Cr 1.30%.

All welding of "Patch Test" plates was performed with $\frac{3}{16}$-in. Type 310 (25 Cr – 20 Ni) electrodes from one manufacturer's lot. The electrodes were stowed during the tests in unopened containers in dry storage. Welds were made in the flat position using a split-weave except that the first two layers were deposited with a full weave. Weav-

(Continued on p. 700)

*Abstract of "Welding Air Hardening Alloy Steels", by Walter H. Wooding, *Welding Research Supplement*, November 1950, p. 552-s – 564-s.



Welding Air Hardening Steels

(Continued from p. 698)

ing was limited to three times the electrode diameter. The mean diameter of the circular groove was varied from 4 to 8 in. in 1-in. increments. Duplicate patch assemblies were made of each steel for each condition of preheat and interpass temperature used in the study. The completed assemblies were radiographed after machining the welds flush on both sides of the assembly and, where no cracks were indicated, the assemblies were sectioned for macroscopic examination.

The Type B steel was studied first to determine the restraint level (minimum patch diameter) at which welds could be made under preheat and interpass temperature conditions normally practicable in fabrication. These are regarded as a preheat from 70 to 100° F. and interpass of 300° F. maximum. In the tests, interpass temperature was not permitted to drop below 100° F. It was found that the maximum restraint level for satisfactory welding of Type B steel is between the 5 and 6-in. patch diameter.

With the Type A steel, using various conditions of preheat and interpass temperature, it was found that a preheat of 600° F. and an interpass temperature of 600 to 700° F. were required to obtain a satisfactory welded joint at the restraint level of the 6-in. patch diameter. However, satisfactory welds could be obtained under these temperature conditions, even with the 4-in. patch diameter.

In all cases, following the completion of welding, the assembly remained in the welding and heating jig until the prescribed temperature was uniform throughout the assembly. This equalization usually occurred in about one hour.

Because these preheat and interpass temperatures are considered impractical for large fabrication, the method of "groove cladding" was investigated. The root opening of the groove was increased to allow for the cladding layers but the mean patch diameter was maintained at 6 in. The cladding layers were approximately ⅛ in. thick on the groove face. It was possible to make satisfactory welds using this cladding method in the 6-in. patch

(Continued on p. 702)

Welding Air Hardening Steels

(Begins on p. 698)

diameter with a preheat of 70 to 100° F. and a maximum interpass of 150° F.

Upon checking these welding conditions in production activities, it was found that with the high preheat and interpass temperatures established for the unclad butt joints cracking occurred in the heat affected zones. The "cladding" method, however, produced satisfactory welded joints in the Type A steel at the low temperatures previously indicated. A further check on the procedure used for the unclad butt welds revealed that the preheat temperature had not been maintained after completion of the weld in the production tests as had been done in the laboratory tests. This suggested the possibility that the thermal behavior of the Type A steel might be partly responsible for the different behavior in the two tests.

Investigation of temperature-dilation characteristics of the two steels indicated similarity and Jominy end quench tests indicated similar hardenability.

Isothermal transformation characteristics of the Type A steel were investigated by depositing with the Type 310 electrode a single weld bead 1 in. long on pieces of plate 2 x 1 x ¾ in. under a variety of preheat temperatures. The weld bead was deposited, using a voltage-control machine welder, parallel with the 2-in. dimension of the plate specimen. This was parallel with the major direction of rolling of the plate. Preheat temperatures of 175 to 900° F. were used in 50° F. increments. After welding, each specimen was held at the preheat temperature for a predetermined period of time and then quenched in ice water at 32° F. With preheats of 415 to 900° F., the welded specimens were held at temperature for periods from 2½ to 400 min. and from 18 to 120 hr. With preheats of 175 to 400° F., the time of hold before quenching was 10 min.

Martensitic transformation characteristics of the Type A steel were determined using preheat temperatures of 175 to 400° F. After welding, each specimen was held at the

(Continued on p. 704)

Welding Air Hardening Steels

(Continued from p. 702)

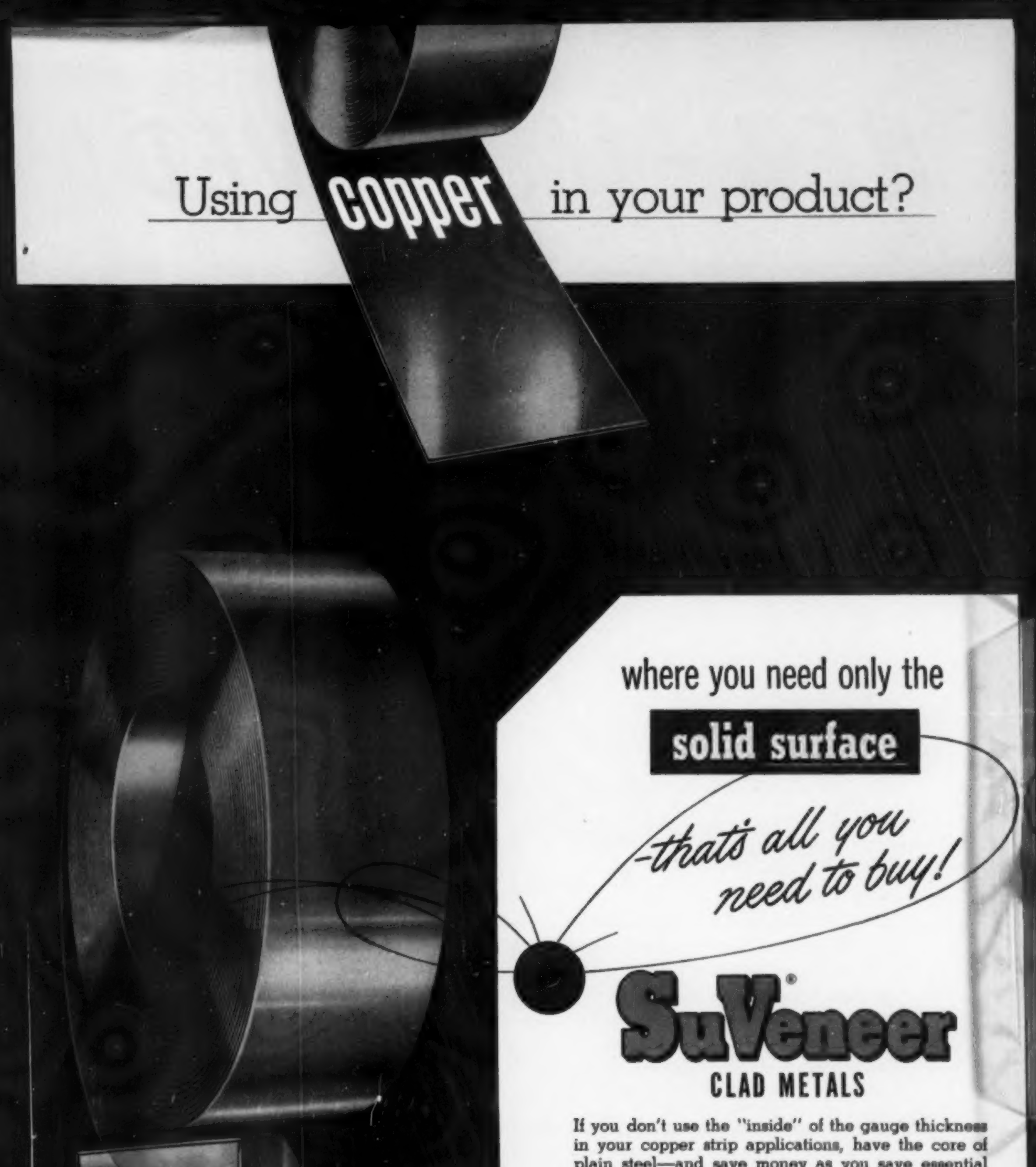
preheat temperature for 10 min. followed by tempering at 850° F. for 30 min. and quenching in water at 32° F. Specimens were sectioned normal to the weld bead immediately upon reaching room temperature and prepared for micro-examination at 200× to determine the per cent of transformation product occurring in the heat affected zone of the plate adjacent to the weld bead.

In a number of the weld bead specimens, welded at preheat temperatures well above the martensitic transformation temperature, underbead cracks were found. These cracks were not found where transformation had progressed sufficiently to form about 8% of bainite in the heat affected zone. At 700° F., cracking persisted up to a 96-hr. hold at that temperature; specimens quickly cooled to below the martensitic transformation temperature and tempered at 850° F. prior to quenching to 32° F. did not show cracks. It should be noted that these cracks occurred at comparatively low levels of restraint as represented by the weld bead specimen. Therefore, it is not believed that hydrogen was a factor in the underbead cracking observed since a 40-min. hold at 450° F. showed no cracking whereas at 700° F. a 96-hr. hold was required to accomplish this result.

On the basis of the transformation data obtained, it is indicated that a one-hour hold at temperature from 400 to 600° F. does not develop transformation product much in excess of the minimum required to avoid underbead cracking. At temperatures below 400° F., it would appear that sufficient transformation could not take place without an excessively long holding time and it is probable that, in the patch test, the restraint imposed by the 6-in. patch diameter at these lower temperatures developed stresses exceeding the fracture stress of the heat affected zone.

In view of these data, and the general assumption that preheating effectively reduces the cooling rate by reducing the rate of heat dissipation, it was thought desirable to study the influence of preheat

(Continued on p. 706)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Welding Air Hardening Steels

(Continued from p. 704)

upon cooling rate. This was accomplished by use of the patch test in a 24 x 24 x 1-in. plate with a 6-in. patch diameter together with a single weld bead test in which a 10-in. long weld bead was laid in the center of a 12 x 12 x 1-in. plate. Preheat temperatures up to 500° F. were used in the weld bead test but a single preheat of 150° F. was used for the patch test.

The heat affected zone cooling rate occurs in two stages. The first stage, which exists from 20 to 40 sec. after weld deposition, appears to be associated with the quenching effect of the base metal. The second and final stage, in which the rate of cooling is much reduced, appears to be associated with heat radiation from the plate surface. The only major differences to be noted between the various preheats are the temperatures at which the first stage changes to the second stage. This change occurs at 800, 700, 600, 425 and 375° F. for preheat temperatures of 500, 400, 300, 150 and 70° F., respectively. In the patch test this change occurs at about 800° F.

With the same preheat temperature of 150° F., the weld bead and the patch test indicate comparable cooling rates during the first stage. However, during the second stage the weld bead specimen shows a cooling rate about twice as great as that of the patch test specimen.

From the test data it is indicated that preheat has no appreciable effect in reducing the severity of base metal quench. Also, preheat does not affect the cooling rate associated with heat radiation from the plate surface sufficiently to permit formation of high-temperature transformation product prior to reaching the martensitic transformation temperature.

It is only by regulation of preheat and interpass temperatures between 450 and 600° F. and holding this temperature for 10 to 12 hr. after welding that satisfactory welds can be obtained under high levels of restraint with the Type A steel. This is considered to be impractical for heavy fabrication and the one alternative appears to be use of the cladding method under high restraint. W. L. WARNER


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Clad Steel Plate

(Continued from p. 672) successful process, but there were many times during its development when the research department was aware of what they did *not* know — and there were few opportunities to indulge in the folly of dogmatism. The forces exerted in the "Big Mill" to bond the hot metals readily found any weak spots in the welds that were supposed to hold the assembly as a unit. The parting compound would sag or shift. The two metals often acted obstinately as though they did not want anything to do with each other. Other difficulties too numerous to mention appeared singly or *en masse* during those days — and nights.

The most fundamental requirement was a perfect and homogeneous bond between the carbon steel and the stainless, if these clad steels were to serve as corrosion resistant materials of construction. Unbonded areas near welds and openings would permit the corrosive contents in a vessel to enter and attack the carbon steel backing plate. The two metals had to form an integral bond; there could be no compromise in this respect. It was of equal significance that the cladding should roll uniformly in its thickness across the full area of the plate, since bare or thin spots might result in early failure during service. The metallurgical structure of the expensive surface layer had to be maintained or restored in the finished product in order to be fully resistant to corrosion. For the same reason it must be free of heating effects and mechanical imperfections. These and other conditions had to be met, yet the procedures had to conform with mill facilities and schedules.

The significant factors for the production of these clad steels were the parting compound, nickel plating of the corrosion resistant alloys, and the world's largest installation for descaling with sodium hydride.

The parting compound is applied to the surfaces of the two corrosion resistant slabs that face each other in the sandwich. It prevents them from welding together in the rolling mill. Since steel ingots and clad steel assemblies are heated in the soaking pits in a vertical position, to utilize the pit area properly, the parting compound must not run or sag, even after 10 to 16 hr. firing and a temperature *(Cont. on p. 710)*

Clad Steel Plate

(Begins on p. 671) of 2350 to 2400° F. Any displacement would allow the clad surfaces to stick together during rolling.

The nickel plating is largely responsible for the integral bond between surface layer and its backing. It prevents the formation of chromium oxide, fatal to strength and continuity. But an equal benefit is that this nickel layer is a barrier to carbon migration from the carbon steel backing plate into the cladding. It thus preserves the composition of the stainless alloy, unimpaired throughout its entire thickness.

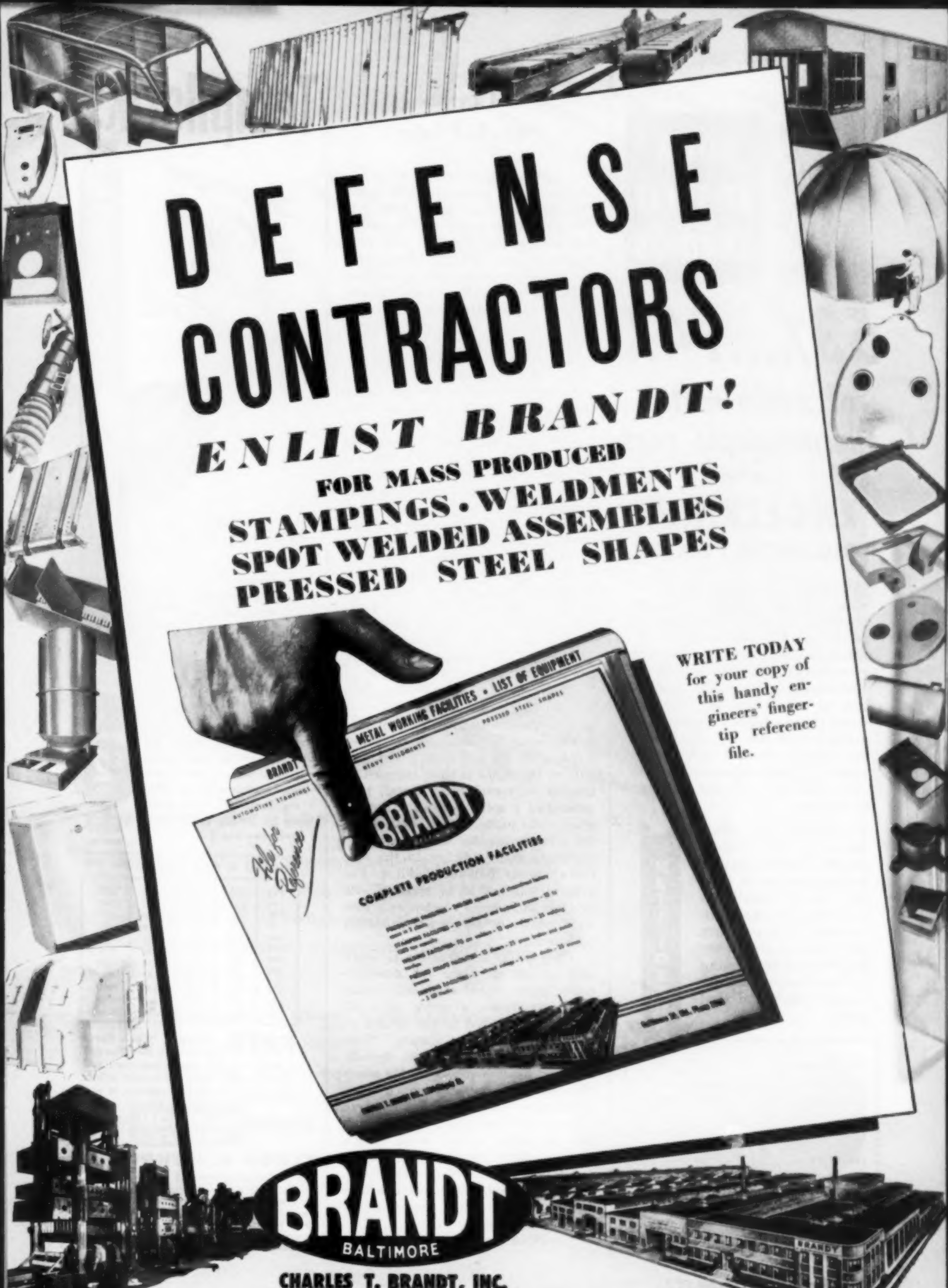
Final cleaning and surface treatment are of utmost importance for a long life of usefulness. Sodium hydride descaling and subsequent acid washes remove surface impurities by chemical means, thus retaining the smoothness of rolled plate. In this respect, the sandwich method provides the maximum protection of the valuable surface, since it is sealed completely within the pack during heating and rolling.

As to the composition of the backing material or base metal, the normal grades of the A.S.M.E. boiler code and other standard specifications for carbon and low-alloy steels may be used. This includes the 70,000-psi. minimum tensile types, if desired. The most common selection is A.S.T.M. A-285 or A-201, both 55,000-psi. minimum tensile strength. The corrosion resistant metals commercially and regularly clad on carbon steel include nearly all the varieties of stainless steels, nickel, Monel, Inconel, copper and silver; aluminum clad steel is the latest addition to the group. Tantalum and Hastelloy clad steels may appear in the near future.

The dimensions of commercially available plates range from $\frac{3}{16}$ to 6 in. in total thickness, and up to 480 in. in length or 178 in. in width. (The available length and width vary with the total weight of the plate involved.) Double clad steels are also made — stainless, for example, on both sides of carbon steel — and find their general application as partitions in tanks. Pressure vessel heads made of clad steels are hot spun to the same shapes and gages as are carbon steel heads.

The clad steels are generally supplied to an ordered thickness of cladding, expressed in a percentage

(Continued on p. 712)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Clad Steel Plate

(Continued from p. 710)

of the total composite thickness. The possible range varies from 5 to 50%, although industry generally has standardized on 10 and 20%. However, one field of application has become accustomed to a fixed thickness of cladding; for example, $\frac{3}{16}$ in. stainless steel will be used on ⅝-in. or 3-in. thick carbon steel base metal.

All these advantages would be sullied if the fabricating operations were difficult. As to this important fundamental requirement, the clad steels are rolled, bent and formed, hot or cold worked, in the same manner and to the same tolerances as used for carbon or low-alloy steels. Thousands of tons have been processed in all the larger fabricating shops in this country with no unusual precautions being necessary.

Clad steel is gas cut with any regular equipment for this purpose when the steel side is placed upward, facing the torch. The flame cuts through the carbon steel and then penetrates the cladding, which otherwise is resistant to ordinary gas cutting.

Welding — Clad steel plates are beveled to any desired type of groove for welding, and carbon steel is deposited by hand or automatic welding to fill the joint. The clad side of the seam is then chipped or ground to sound weld metal, thus providing a suitable groove for the alloy weld metal. This clad side of the joint is usually welded with an electrode that is richer in the special elements than the cladding. For example, 18-8 clad is welded with 25-12 or 25-20 Ni-Cr electrodes. Two weld passes or layers are generally sufficient.

Only a like composition is available as an electrode for commercially pure nickel cladding; under such conditions, a series of small beads is deposited in the groove to keep dilution to a minimum. However, in respect to nickel, specifically, an 80-20 Ni-Cr electrode offers considerable assistance, since these elements, combined with small amounts of iron, produce an Inconel type of alloy in the weld, which offers a high degree of corrosion resistance. Steels, clad with Monel, copper, Inconel, and silver are similarly welded with appropriately selected electrodes.

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x-ray
accessories
Picker

Clad Steel Plate

(Continued from p. 712)

It seems apparent that the chemical and physical properties of these clad steels thoroughly justify their existence. The A.S.M.E. Boiler Code has long accepted them as qualified materials of construction for pressure vessels. In fact, the A.S.M.E. and the A.P.I.-A.S.M.E. codes permit the use of the full, composite thickness of a clad steel in designing vessels to operate under their jurisdiction, provided the two metals be integrally joined and pass a shear test with a minimum bond strength of 20,000 psi. Of the many tons of clad steel plates subjected to this test, none has yielded less than 40,000-psi. shear, and generally they test 45,000 to 50,000 psi., approximately equal to the shear strength of carbon steel itself.

Resistance to Heat Fatigue

For this reason, tray rings and other supports in the interior of a vessel may safely be welded directly to the cladding. Further evidence of a perfect bond has been demonstrated by tests in which 2000 cycles of heating and quenching (1000° F., and even 1800° F., to 400° F.) have been applied to rigid specimens, including steels clad with austenitic stainless having a large difference in coefficient of expansion.

Where distortion and warping occur, due to the high coefficients of expansion found in some of the stainless steels, for example, the lighter gages are better able to maintain their shape, because of the greater proportion of carbon steel which is present.

A fabricating advantage is this: Attachments to heavy hydraulic machinery are more easily made when welded to the carbon side of a clad steel than though the solid special metal were used throughout.

Are there any applications for clad steels aside from mere substitutes for more expensive, solid alloys? As a matter of fact, there are a number of such interesting developments in which clad steels (or properly bonded bimetals) do supply a unique quality or property of their own.

In the way of illustration, an important unit in its operation expels exhaust gases while being immersed in salt water, thus encountering two

(Continued on p. 716)

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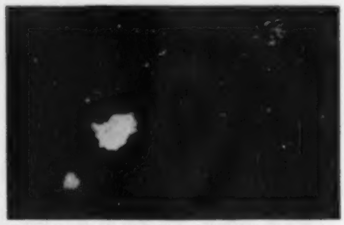

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Clad Steel Plate

(Continued from p. 714)

different corrosive conditions. A double clad steel has been developed for this purpose, with carbon steel between.

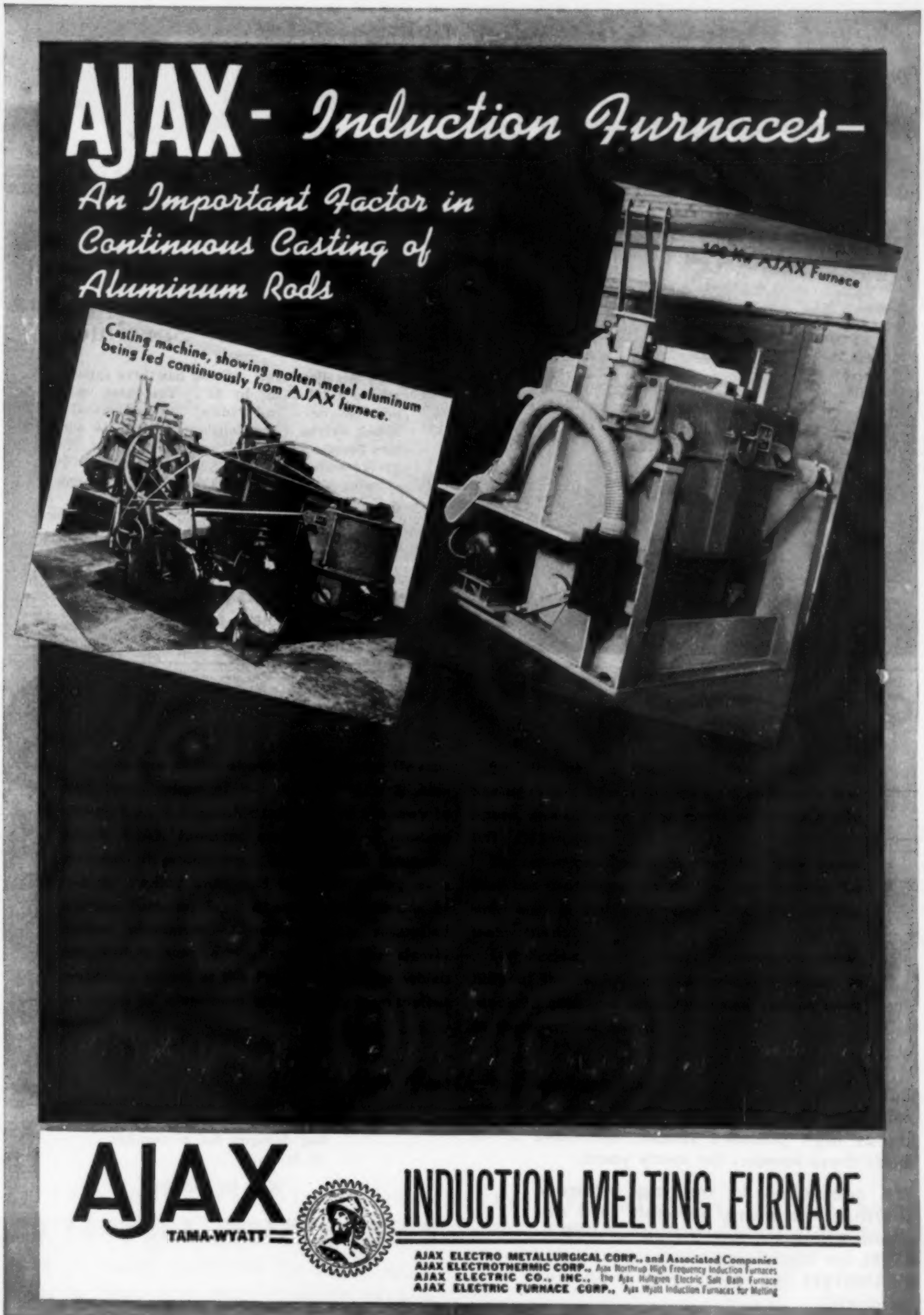
Another example is met in the concentrating of caustic soda. Pure nickel and nickel clad steel provide excellent protection. In some heat exchangers, heavy walled tubes, in which gas is burned, are submerged in a bath of molten caustic. Solid nickel tubes, while they resist chemical attack, become embrittled and fail because of the high sulphur fuel. In such service nickel clad tubes give thousands of hours of continuous service. The caustic attack is resisted by nickel, while the carbon steel on the inside resists the flame. Both metals are needed, as neither one will withstand both corrosive conditions.

Copper clad steel plate is one of the most recently available materials. It has been used for several years in the form of strip; but there were many problems to overcome before it could be made into large and wide plates.

Another example of increasing the strength of a relatively weak material like copper by combining it with carbon steel is found in aluminum clad. It is especially valuable for high-temperature service. In fact, a process involving certain synthetics requires aluminum because of its corrosion resistance, but the operating temperature is too high for the allowable tensile strength of aluminum at that temperature. Here is an industry dependent for its very existence on a particular composite material.

The low thermal conductivity of certain alloys is a well-known drawback in the operation of process equipment. The use of heavy backing mitigates this deficiency, and such clad metal has been used to manufacture a number of items that depend on rapid and uniform heat transfer.

Lastly, all uses for clad steel save a tremendous amount of critical materials in times of heavy demands. It is significantly fundamental that a 10% clad steel enables one ton of stainless to do the work of ten. The same relationship saves equal amounts of nickel, copper, aluminum and many other strategic metals, when so much depends on them.



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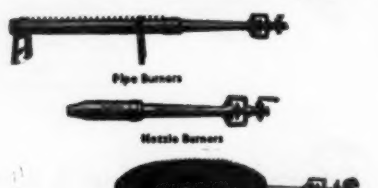

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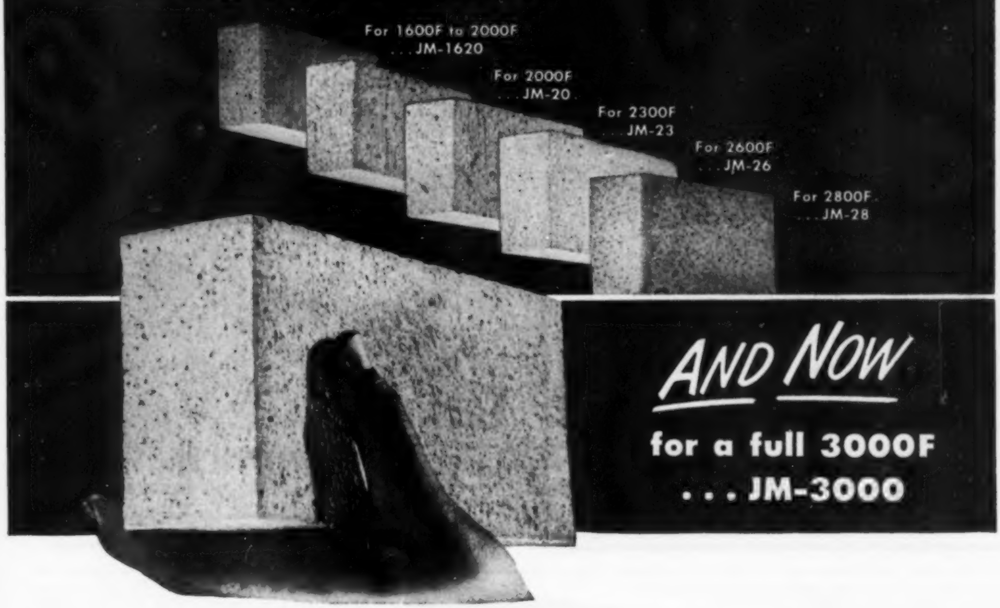


AND NOW for a full 3000F . . . JM-3000

HERE IS AN OUTSTANDING FAMILY of insulating fire brick for back-up or exposed use . . . the only family of its kind . . . that gives you a complete range . . . a *quick heating* insulating fire brick for every purpose.

By taking advantage of the quick heating characteristics of these insulating fire brick, you'll benefit through important savings in fuel because of the quicker rise to proper operating temperature in the furnace. This is a result of the low heat storage capacity and low thermal conductivity characteristics of the brick. These factors are especially important where furnaces are being intermittently operated.

The same materials can also be obtained in large size units as Johns-Manville Insulating Fireblok. This product has many advantages over the smaller size fire brick, from both a construction and stability standpoint. They can be quickly applied because they are easy to cut and fit. J-M Insulating Fireblok provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

Why not have a Johns-Manville insulation expert call to tell you more about ways in which you can save by using these insulations in your furnaces. Write Johns-Manville, Box 290, New York 16, N. Y. for further information.

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage,† percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

† *24-hr simulative service panel test for JM-3000; 24-hr soaking period for other brick.*

* *Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures.*

Note: Above tests are in accordance with A.S.T.M. tentative standards.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville First in INSULATIONS

What does the inside of a billet have to do with a Forging?

Sound billets free from large internal voids, non-metallic inclusions, and visible surface seams are the only kind that a forger can use with any assurance of maintaining a high rate of production. Steel that contains flaws of critical size may open up under the hammer, while clean steel flows uniformly to produce sound, acceptable forgings.

At Bethlehem we take unusual care in manufacturing alloy steels for forging use. Chemical composition and grain size are closely controlled so that the steel will respond to heat-treatment uniformly and with minimum distortion. Billets are cooled slowly in bung-type furnaces, with separate cooling cycles being used for each different composition of alloy steel to avoid cooling cracks. Rolled billets are subjected to macro-etch tests to insure internal cleanness. Nothing is overlooked that might improve the overall quality.

Bethlehem Alloy Steels will go a long way toward helping you turn out a higher percentage of acceptable forgings per ton. We manufacture all of the AISI grades as well as carbon and special steels.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL

PHOSPHATE COATING CHEMICALS FOR SPECIFICATION FINISHES

METAL	GOVERNMENT SPECIFICATION	ACP SPECIFICATION CHEMICAL
STEEL	JAN-C-490, Grade I U.S.A. 57-0-2, Type II, Class C U.S.A. 51-70-1, Finish 22.02, Class C	"GRANODINE"
	U.S.A. 57-0-2, Type II, Class B U.S.A. 51-70-1, Finish 22.02, Class B	"PERMADINE"
	U.S.A. 57-0-2, Type II, Class A U.S.A. 51-70-1, Finish 22.02, Class A	"THERMOIL-GRANODINE"
ALUMINUM	MIL-C-5541 MIL-S-5002 AN-F-20 U.S. Navord O.S. 675 16E4 (Ships)	"ALODINE"
ZINC	QQ-P-416 RR-C-82 JAN-F-495 AN-F-20 U.S.N. Appendix 6	"LITHOFORM"

ACP "GRANODINE"®

"GRANODINE" forms a zinc phosphate coating on steel and zinc surfaces. This non-metallic bond holds and protects the paint finish and thus preserves the metal underneath.

ACP "PERMADINE"®

"PERMADINE" forms an oil-adsorptive zinc phosphate coating on steel, which, when treated with rust inhibiting oil, is highly corrosion resistant.

ACP "THERMOIL-GRANODINE"®

"THERMOIL-GRANODINE" forms a manganese-iron phosphate coating on steel, which, when oiled, provides wear-resistance for rubbing parts — and, when oiled or painted, inhibits corrosion.

ACP "ALODINE"®

"ALODINE", the new ACP protective coating chemical for aluminum, anchors the paint finish and protects the metal painted or unpainted.

ACP "LITHOFORM"®

"LITHOFORM" makes paint stick to galvanized iron and other zinc and cadmium surfaces.

Write for more information on these products. Send for new descriptive folders on the ACP metal-protective, rust proofing and paint bonding chemicals listed in this advertisement.

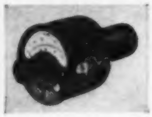
Pioneering Research and Development Since 1914

AMERICAN CHEMICAL PAINT COMPANY

AMBLER, PA.

Manufacturers of METALLURGICAL, AGRICULTURAL and PHARMACEUTICAL CHEMICALS

WHY GUESS THE TEMPERATURE
. . . when you can see it!



THE NEW
PYRO RADIATION PYROMETER

Just sight it . . . and press the button!

Tells spot temperatures instantly in heat-treating furnaces, kilns, forgings and fire boxes. No thermocouples, lead wires or accessories needed! Temperature is indicated on direct-reading dial at a press of the button. Any operator can use it. In two double-ranges for all plant and laboratory needs.

Model No. 1: 1000-1800° F. and 1800-2600° F.
Model No. 2: 1400-2400° F. and 2400-3400° F.

Write for FREE Catalog No. 100.

PYRO OPTICAL PYROMETER

Accurate temperatures at a glance!

Any operator can quickly determine temperatures on minute spots, fast-moving objects and smallest streams. Completely self-contained. No calibration charts or accessories needed. An accurate, direct-reading Pyrometer that pays for itself by helping prevent spoilage. Weighs 3 lbs. Available in 5 temperature ranges (1400° F. to 7500° F.). *Write for FREE Catalog No. 80.*

THE PYROMETER INSTRUMENT COMPANY
New Plant and Laboratory
Bergenfield 8, N. J.

CARL-MAYER HIGH TEMPERATURE FURNACE, recirculating air heater type, for temperatures up to 1200°F., as installed for Timken Roller Bearing Company. ● We also build Conveyor and Batch Type Furnaces up to 2000°F., for heat treating, normalizing, drawing, etc., using gas, oil and other fuels. ● Our many outstanding achievements make it well worth your while to consult Carl-Mayer Engineers on your next installation.

The CARL-MAYER Corp.
3030 Euclid Avenue, CLEVELAND, OHIO.

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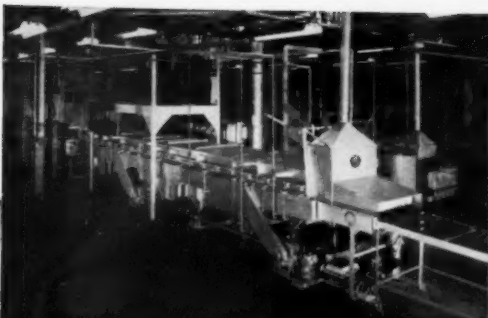
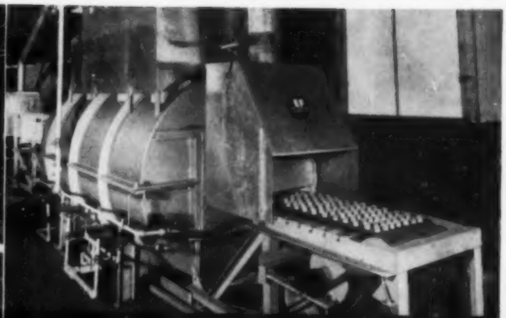


Discharge End of a Large Capacity EF Combination Gas Fired and Electric Sintering Furnace, 60' long



EF Gas Fired Cylindrical Muffle Continuous Furnace for Sintering Nonferrous and Iron Powder Parts.

EF FURNACES

for processing metal powder products

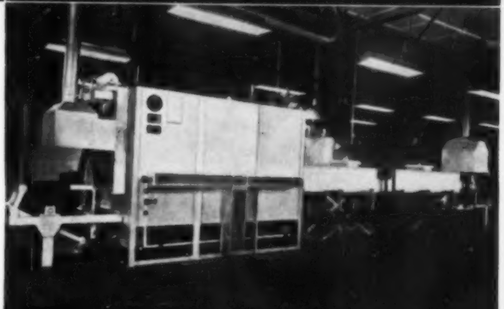
• EF furnaces are built in many sizes and types for sintering a wide variety of ferrous and non-ferrous pressed metal powder products—for bonding metal powder to strip, and other processes.

With our long experience and complete manufacturing facilities we are in position to build the size and type to fit your specific requirements.

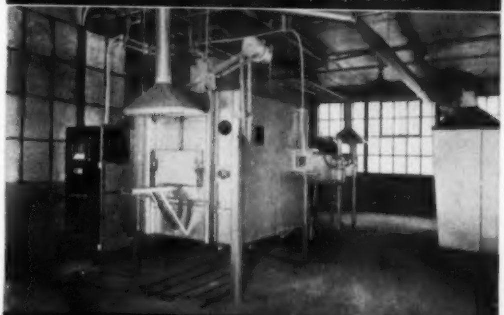
The Electric Furnace Company

Wilson Street Salem, Ohio

Gas Fired, Oil Fired and Electric Furnaces For Any Process, Product or Production



Standard EF Wire Mesh Belt Type Sintering Furnaces are Available in Sizes to Meet Many Requirements.



Small EF Hand Operated Pusher Type Electric Furnace Suitable for Experimental and Small Production Runs

Trayloads of Clean, Uniform, Finished Parts Leave This EF Gas Fired Furnace — Continuously and Automatically

Metal Powder may be Fused on Six 3'' Strips of Steel, Simultaneously and Continuously in this EF Furnace